# RESEARCH





# Effect of a tailor-made hydrotherapy on physical functions in patients after unilateral unicompartmental knee arthroplasty—A feasibility study

Wai-Wang Chau<sup>1†</sup>, Mei-Yan Lau<sup>1†</sup>, Tsz-Lung Choi<sup>2</sup>, Gloria Yan-Ting Lam<sup>2</sup>, Michael Tim-Yun Ong<sup>1\*</sup> and Kevin Ki-Wai Ho<sup>1</sup>D

# Abstract

Introduction Unicompartmental knee arthroplasty (UKA) is one of the treatment options for patients whose osteoarthritis involves one out of the 3 compartments. Patients who underwent UKA benefited from shorter hospital stays, better range of motion, and lower risk of postoperative complications compared with patients who underwent total knee arthroplasty (TKA). Hydrotherapy is being introduced complementary to conventional postoperative rehabilitation programs. No report on the use of hydrotherapy evaluating physical functions on patients who underwent UKA leads us to carry out the present study. This is a feasibility study to investigate the effects of hydrotherapy on physical functions in patients after primary unilateral UKA.

Methods A retrospective cohort study recruited 68 patients who underwent primary unilateral UKA. Nineteen patients were allocated to the hydrotherapy group and 49 patients were in the convention group. Patients in the hydrotherapy group received hydrotherapy and conventional physiotherapy, and the convention group was given conventional physiotherapy only. The primary outcome was Knee Society Function Score (KFS) measured before surgery, six months, and one year after UKA. Self-reported walking tolerance, Timed Up and Go Test (TUGT), and 30-s Chair Stand Test (30CST) were conducted before and after the completion of rehabilitation. Pain and range of motion were also covered.

**Results** Hydrotherapy group showed significantly higher KFS at 6 months (P=0.038) and one year (P=0.030) after operation. Range of motion flexion and extension in the hydrotherapy group were significantly improved at postoperative 4 weeks and the last session of rehabilitation. Self-reported walking tolerance in the hydrotherapy group was significantly longer at the last session (P=0.011). No significant difference was found in TUGT, 30CST, and pain between the two groups after rehabilitation. In both groups, all outcomes were significantly better as compared to preoperative findings.

**Conclusion** Patients who underwent UKA after hydrotherapy complementary to conventional physiotherapy showed significant improvements in functions, range of motion, and time to tolerating walking before rest. Pain,

<sup>†</sup>Wai-Wang Chau and Mei-Yan Lau contributed equally to this work.

\*Correspondence: Michael Tim-Yun Ong michael.ong@cuhk.edu.hk Full list of author information is available at the end of the article



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mobility, balance, leg strength, and endurance were comparable between the two groups. Combination of hydrotherapy with conventional postoperative physiotherapy rehabilitation yielded even better outcomes than conventional physiotherapy alone. Further research with advanced study design, larger sample size and longer follow-up periods for patients who underwent UKA is recommended.

Trial registration NCT06459960, retrospectively registered on 13.06.2024 (ClinicalTrials.gov).

Keywords Hydrotherapy, Unicompartmental knee arthroplasty, Physical function, Physical therapy, Rehabilitation

# Introduction

Osteoarthritis (OA) of the knee is one of the most common chronic degenerative joint diseases, primarily afflicting aging population, limiting joint movement, and causing disability because of pain and stiffness. Prevalence of radiological knee OA increased with age, being 64.1% in those aged 60 and over, and higher in females than in males [1]. Surgery is the subsequent treatment after conservative management fails. Unicompartmental knee arthroplasty (UKA) is one of the treatment options for patients whose osteoarthritis does not involves all compartments [2]. Patients who underwent UKA benefited from shorter hospital stay, better range of motion, and lower risk of postoperative complications, compared with their counterparts who received total knee arthroplasty (TKA) [2]. Our team investigated the correlation between femoral and tibial component axial rotational alignment and functional outcomes of 83 Oxford UKAs received by 67 patients with isolated medial or lateral compartment knee osteoarthritis [3]. We found that femoral component axial rotation between 2° and 6° external rotation, and tibial component axial rotation between 1° and 8° external rotation correlated with significantly better functional scores, with the highest functional scores observed at 3°-4° external rotation for femoral component, and  $4^{\circ}-5^{\circ}$  external rotation for tibial component [3].

After knee arthroplasty, physiotherapy rehabilitation is a part of non-invasive treatments leading to a successful outcome after surgery. Postoperative physiotherapy, including exercises aiming at improving range of motion, muscle strengthening, achieving body balance, and gait training, was shown to improve range of motion and muscle strength of the knee [4, 5]. An European review on exercises after knee arthroplasty reported improvements in various functional outcome measures [5]. Recently, hydrotherapy has gained popularity for its use playing an important role in the rehabilitation programme after knee arthroplasty. Hydrotherapy is the external or internal use of water in any of its forms (water [liquid], ice [solid], steam [gas]) for health promotion or treatment of various diseases, at various temperatures, pressures, durations, and sites [6]. Hydrotherapy has been widely employed in various musculoskeletal and neurological conditions, from paediatric to geriatric populations [7].

Benefits of warm-bathing hydrotherapy include relieving pain and muscle spasm through warmth, reducing loads of joints through buoyancy, decreasing edema through pressure from immersion, and producing resistance to movement through turbulence and hydrostatic pressure [7, 8]. Studies proved that hydrotherapy could decrease pain, and improve physical functions, muscle strength, and quality of life in patients after total hip or knee arthroplasty [8].

To the author's knowledge, no study examined the effect of hydrotherapy on patients after UKA (all related articles were on post-TKA patients). It is, therefore, worth investigating the effects of hydrotherapy on the clinical outcomes of patients following UKA. This was a feasibility study aiming at investigating the effects of a tailor-made hydrotherapy rehabilitation programme on improving the physical functions of patients after primary unilateral UKA. We hypothesized that the physical functions of post-UKA patients, compared with post-TKA patients, are better after the incorporation of hydrotherapy to the current joint replacement surgery physiotherapy rehabilitation.

## Methods

## Study design

This retrospective cohort study was conducted in accordance with the Declaration of Helsinki. Ethical approval was received after reviewing by the local ethics review board (Reference number: CRE2020.586). All test procedures were conducted according to the principles adopted in the Declaration of Helsinki and ICH-GCP. The study adhered to CONSORT guidelines. This study registered with clinicaltrials.gov and the trial registration number was NCT06459960.

## **Patient recruitment**

Patients aged 18 or above who underwent primary UKA using Oxford<sup>®</sup> Partial Knee (Zimmer Biomet, UK) at a tertiary hospital between the years 2018 and 2019 were recruited. Patients with the following conditions were excluded: (1) had major postoperative complications, (2) received revision or robotic-assisted surgery or bilateral knee arthroplasty, (3) incomplete follow-up, (4) received postoperative physiotherapy rehabilitation other than at

the tertiary hospital, (5) had cognitive impairment, or (6) were unsuitable for exercise training. Comorbidities included hypertension and hyperlipidaemia. The patients included were mostly rated Grade II on ASA.

## Grouping

A total of 68 patients were included and divided into (1) Hydrotherapy group (Hydrotherapy) (n=19) or 2) Convention group (Convention) (n=49). Figure 1 illustrates workflow of the patient recruitment. Figure 2 graphically shows the timeline of this study.

# Anaesthesia

All patients were assessed by a specialist anaesthetist to determine the optimal mode of anaesthesia. General anaesthesia or regional anaesthesia was used, depending on the clinical situation. All patients also intraoperatively received intra-articular infiltration anesthesia, which consisted of NSAIDs, adrenaline, and local anaesthetic agents.

## Walking aids used and discharge standard

Walking aid usage was based on the patients' recovery situation, balance, and stability. All patients started using walking frames immediately following surgery. They advanced to use of walking sticks or crutches when their recovery improved. All patients achieved at least Modified Function Ambulatory Category (MFAC) IV/V before being discharged home.

#### Interventions

Patients who were scheduled to have UKA received prehabilitation before surgery (about 2 months before surgery consisting of 4 sessions) as a regular regime in our total joint center ("Physiotherapy starts", Fig. 2). Postoperative rehabilitation started at postoperative day 0 for in-patients. Most of the patients who underwent UKA were clinically fit for discharge within 3 days after surgery ("Discharge", Fig. 2). Postoperative rehabilitation for the out-patients usually started 1–2 days after discharge. All patients finished the 8-week rehabilitation programme. Patients in the Hydrotherapy group usually started hydrotherapy treatment at postoperative 8 weeks (i.e., 2 months after UKA) and completed after 4 weeks.

#### **Convention group**

The conventional physiotherapy rehabilitation program included: (1) knee mobilization exercises, such as static bike and heel sliding board, (2) muscle stretching exercises of hamstrings and calf, (3) muscle strengthening exercises, such as adding cuff weights for quadriceps strengthening and wall slide with gym ball, and (4) balance and functional training, such as stepping or single-leg standing on soft foam, stepping exercises on various heights of steps (Fig. 3 series).

To recall, physiotherapy rehabilitation program started during the perioperative period and continued after surgery twice a week, for a total of 8 weeks.

# Hydrotherapy group

Patients practised the rehabilitation exercises in a heated pool (32 °C). Exercises included: (1) knee mobilization exercises, (2) muscle stretching exercises, (3) muscle strengthening exercises, such as wall slide, leg press with life ring, and lunges, (4) Balance and functional training: single-leg standing, tandem walking, heel walking and tip-toe walking, and (5) balance functional training: cycling in water, fast walking and running (for patients in Hydrotherapy group only) (Fig. 4).

Hydrotherapy usually started at postoperative 8 weeks (Fig. 2). Patients practised once a week for a total of four weeks, following the completion of conventional physiotherapy rehabilitation.

# Data collection time-points

Demographic characteristics were collected at patient recruitment. Outcome data were harvested by following either the clinical follow-up schedule (preoperative, postoperative 6 months and postoperative 1 year) or rehabilitation program (Post-op 1st session, Post-op 4 weeks and Post-op last session).

# Outcome assessments

# Primary outcome

Primary outcome was Knee Society Function Score (KFS). KFS was designed to provide a simple scoring system to objectively quantify the outcomes of patients before and after TKA [10]. KFS was recorded at (1) Preoperative, (2) Postoperative 6 months, and (3) Postoperative 1 year.

## Secondary outcomes

Two sets of secondary outcome data were collected. The 2 sets were different in terms of data-collection time points. The first set comprised: (1) Numeric pain rating scale [11] and (2) Passive range of motion—Flexion and Extension, measured using a goniometer and clinically assessed by a joint specialist [12]. Those data were taken at (1) postoperative first session, (2) Postoperative 4 weeks, and (3) postoperative last session of rehabilitation program. The second set involved: (1) self-reported walking tolerance (minutes) [13], (2) timed Up and Go Test (TUGT) (seconds) [14], and (3) a 30-s Chair Stand





Fig. 2 Illustration of the timeline for this feasibility study

Test (30CST)(repetitions) [15]. Those data were collected at (1) Postoperative first session, and (2) Postoperative last session of rehabilitation program.

#### Sample size calculation

The sample size in each group was determined by (1) our patient referral criteria to receive hydrotherapy and (2) Cosmin criteria [16, 17]. Medical records of our joint center showed that 1 out of 4 patients who underwent UKA met the referral criteria.

Total sample size required was calculated using G\*Power 3.1.9.7. The study design was chosen as "Test of difference with two independent means (two groups)", complementary to the following information (1) two tailed null hypothesis, (2)  $\alpha = 0.05$ , (3)  $\beta = 0.95$ , and (4) power at 0.95. Effect size (=0.94) was calculated based on the outcomes from a relevant publication on the changes in Knee Society Function Score [18]. Adding 10% of the potential drop-out rate, the calculated sample size was 68.

# Statistical analysis

All continuous data were expressed as mean and standard deviation (SD) and categorical variables as n (%), where appropriate. Basic demographics (age, sex, surgical side, body height, body weight, body mass index (BMI) between Hydrotherapy group and Convention group were compared using the Student's *t*-test (numeric variables) or Chi-square test (categorical variables). Primary outcome (KFS) and secondary outcomes (self-reported waking tolerance, TUGT, 30CST, NPRS, and passive ROMs) were compared between Hydrotherapy group and Convention group using Student's *t*-test. Longitudinal time-dependent comparisons of all primary and secondary outcomes mentioned were made using ANOVA. Post hoc Tukey's honestly significant difference test was performed to correct and reduce the risk of identifying false significant differences between groups due to chance. IBM Corp. Released 2022 IBM SPSS Statistics for Windows (Version 29.0. Armonk, NY: IBM Corp) was used for data analysis. A P < 0.05 was considered statistically significant.

#### Results

Sixty-eight patients were recruited, of which 19 patients were in hydrotherapy group (Hydrotherapy) and 49 patients were in convention group (Convention).

## **Basic characteristics**

Age, sex, surgical side, body height, body weight, and BMI showed no significant difference between Hydrotherapy group and Convention group (Table 1). Table 2 compares outcomes between Hydrotherapy group and Convention group.

There was no significant difference in all outcomes at the first data collection time point (before operation or at postoperative 1st session) between Hydrotherapy group and Convention group. Hydrotherapy group 1. Knee mobilization exercises



(a) Heel sliding board for knee mobilization



(b) Static bike for knee mobilization

2. Muscle stretching exercises of hamstrings and calf



(a) Hamstrings stretching exercise; (b) Calf stretching exercise

4. Balance and functional training



Stepping and single-leg standing exercises on soft foam



(a) Stepping exercise on steps with different heights; (b) Lower limb ergometer

3. Muscle strengthening exercises



(a) Cuff weights for quadriceps strengthening; (b) Nustep for lower limb muscle strengthening;

(c) Wall slide with fitball for lower limb muscle strengthening

Fig. 3 Illustrations of conventional physiotherapy rehabilitation program

showed significantly higher KFS than Convention group at Postoperative 6 months (P=0.038) and postoperative 1 year (P=0.030). Similar results were observed in the flexion and extension ROM. At Postoperative last session, patients in the Hydrotherapy group showed significantly higher walking tolerance (P=0.011) compared to those in the Conventional group. No statistical significance was found in terms of NPRS, TUGT, and 30CST.



(a) Knee extension; (b) Knee flexion; (c) Kneeling

2. Muscle stretching exercises







- (a) Hamstring stretching with life ring; (b) Calves stretching; (c) Quadriceps stretching with life ring
- 3. Muscle strengthening exercises



(a) Wall slide; (b) Leg press with life ring; (c) Lunges **Fig. 4** Illustrations of hydrotherapy rehabilitation program [9]

#### Longitudinal comparisons

All outcomes showed significant improvements over time (statistically significant in all overall comparisons) (Table 3). KFS at all 3 time points were persistently higher in Hydrotherapy group than in Convention group (Fig. 5). NPRS and both flexion and extension passive ROM were significantly improved at postoperative 4 weeks and postoperative last session in both groups. Post hoc comparisons showed no statistical difference in passive ROM between postoperative 4 weeks and postoperative last session in both groups. After hydrotherapy, patients showed better outcomes than those in the convention group at the last session of self-reported walking tolerance, TUGT and 30CST.

#### 4. Balance and functional training



Balance training: (a) Single leg standing; (b) Tandem walking; (c) Heel walking; (d) Tip-toe

walking

5. Balance and functional training - Cycling in water, fast walking and running



(a) Cycling in water; (b) Quick forward walking; (c) High knee running in place

# Discussion

This was a feasibility study on the effect of tailor-made hydrotherapy rehabilitation on patients after UKA. The outcomes of patients who underwent UKA following hydrotherapy combined with conventional rehabilitation were compared to those who received conventional rehabilitation only. Given the baseline characteristics of patients from both groups were similar, patients in hydrotherapy group performed significantly better function 6 months and 1 year after UKA. Moreover, the range of motion, of both flexion and extension, also significantly improved at the 4th week and the last session of the rehabilitation program after UKA. Self-reported walking tolerance was found to be significantly better in Hydrotherapy group than in Convention group at

Table 1	Basic demograp	hics of the	68 patients
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	Hydrotherapy group ( <i>n</i> = 19)	Convention group ( <i>n</i> = 49)	P-value
Age (years)	67.95±4.58	70.53±5.85	0.089
Sex			
Male	7 (25.9) (36.8)	20 (74.1) (40.8)	1.000
Female	12 (29.3) (63.2)	29 (70.7) (59.2)	
Surgical side			
Left	9 (26.5) (47.4)	25 (73.5) (51.0)	1.000
Right	10 (29.4) (52.6)	24 (70.6) (49.0)	
Body height (cm)	158.16±8.32	157.88±8.14	0.900
Body weight (kg) BMI (kg/m²)	71.68±11.14	70.06±9.87	0.559
Mean	28.68±4.15	28.06±3.02	0.501
Normal <sup>a</sup>	0	1 (100.0) (2.0)	0.771
Overweight <sup>a</sup>	3 (33.3) (15.8)	6 (66.7) (12.2)	
Obese <sup>a</sup>	16 (27.6) (84.2)	42 (72.4) (85.7)	

<sup>a</sup> BMI (Asian Standards) was used according to the WHO/IASO/IOTF. The Asia– Pacific perspective: redefining obesity and its treatment. Health communication Australia Pty Ltd.; 2000. Where BMI below 18.5 is underweight; from 18.5–22.9 is normal; from 23–24.9 is overweight; from 25–34.9 is obese

the postoperative last session of rehabilitation program. NPRS, TUGT and 30CST did not show any statistical difference between these 2 groups before and after the rehabilitation program. All outcomes demonstrated significant improvements over time.

Performing an Ovid MEDLINE search on either "total knee arthroplasty" or "unicompartmental knee arthroplasty" generated the same MeSH (Medical Subject Headings) term "Arthroplasty, Replacement, Knee", together with keyword search words (total knee arthroplasty.mp. and unicompartmental knee arthroplasty. mp.). In conjunction with the Ovid search string "hydrotherapy.mp. ("hydrotherapy" as a keyword) or Hydrotherapy/(MeSH term) retrieved the same number of articles. None of the articles discussed patients who underwent UKA. In a comparative study of a total of 100 patients who underwent TKA between the year 2008 and 2020 receiving postoperative aquatic exercise (N=33), land exercise (N=21), and home exercise (N=46), all study groups demonstrated improved pain level and passive ROM [19]. However, statistical significance had not been reached for pain level (instrument used: VAS). Improved hip and knee muscle strength, as well as thermodynamics, hydrostatic pressure, and buoyancy (the main properties of water), might explain the pain improvement [19]. **Table 2** Comparisons of outcomes at 3 time-points betweenHydrotherapy group and Convention group

Outcomes	Hydrotherapy group (n = 19)	Convention group (n=49)	P-value
Knee Society Function Sco	ore		
Preop	$60.00 \pm 13.33$	$55.61 \pm 10.98$	0.169
Postop 6 months	$78.95 \pm 14.59$	$70.82 \pm 14.12$	0.038*
Postop 1 year	83.42±12.92	$74.59 \pm 15.34$	0.030*
Numeric Pain Rating Scale			
Postop 1st session	$3.95 \pm 1.31$	$4.10 \pm 1.71$	0.724
Postop 4 weeks	$0.95 \pm 1.27$	$1.20 \pm 1.32$	0.470
Postop last session	$0.00 \pm 0.00$	$0.08 \pm 0.45$	0.433
Passive range of motion o	f knee (degrees)		
Flexion			
Postop 1st session	99.21±6.51	$95.10 \pm 12.31$	0.080
Postop 4 weeks	112.21±6.55	108.16±8.76	0.043*
Postop last session	118.16±5.33	$113.06 \pm 7.76$	0.011*
Extension			
Postop 1st session	$2.11 \pm 3.04$	$4.29 \pm 5.40$	0.102
Postop 4 weeks	$0.26 \pm 1.15$	$2.14 \pm 3.06$	< 0.001*
Post-op last session	$0.26 \pm 1.15$	$1.43 \pm 2.70$	0.015*
Self-reported walking to	plerance (minutes)		
Post-op 1st session	$5.26 \pm 1.15$	$5.61 \pm 2.63$	0.580
Post-op 4 weeks	-	-	-
Post-op last session	$71.84 \pm 29.40$	$54.90 \pm 21.37$	0.011*
Timed Up and Go Test (	seconds)		
Post-op 1st session	$40.58 \pm 10.43$	$50.49 \pm 20.98$	0.054
Post-op 4 weeks	-	-	-
Post-op last session	$10.11 \pm 2.33$	$11.43 \pm 4.19$	0.199
30-s Chair Stand Test (re	petitions)		
Post-op 1st session	$1.74 \pm 2.51$	$1.90 \pm 2.82$	0.828
Post-op 4 weeks	-	-	-
Post-op last session	$12.21 \pm 3.41$	11.47±3.84	0.464

<sup>\*</sup> Statistical significance (P < 0.05)

Furthermore, hydrotherapy was suggested to be introduced shortly after TKA because of the obvious joint loading reduction subsequent to pain reduction, and the benefits showed no inferiority to conventional physiotherapy alone [19]. A systematic review and meta-analysis [20] reviewing 11 randomized control trials published in 2018, and one of the study compared hydrotherapy with conventional (land-based) physiotherapy, and landbased physiotherapy alone [21]. Hydrotherapy-added groups demonstrated statistically significant improvement in activity [20]. Moreover, hydrotherapy was found to be safely delivered to patients as early as 4 days after total knee replacement surgery without increasing the risk of wound infection after applying waterproof wound dressing [22]. The results from the current study are comparable to the findings mentioned above: (1) significant improvement in pain levels and passive ROM, (2) changes

P-value

<0.001\* <0.001\* *P*-value

<0.001\* <0.001\*

<0.001\* <0.001\*

0.007\* 0.001\*

< 0.001\*

< 0.001\*

< 0.001\*

< 0.001\*

< 0.001\*

< 0.001\*

 $71.84 \pm 29.40$ 

 $54.90 \pm 21.37$ 

10.11±2.33

 $11.43 \pm 4.19$ 

 $12.21 \pm 3.41$ 

 $11.47 \pm 3.84$ 

Outcomes	Pre-op	Post-op 6 months	Post-op 1 year			
Knee Society Function Score						
Hydrotherapy group	$60.00 \pm 13.33$	$78.95 \pm 14.59$	83.42±12.92			
Convention group	55.61±10.98	70.82±14.12	$74.59 \pm 15.34$			
Outcomes	Post-op 1st session	Post-op 4 weeks	Post-op last session			
Numeric Pain Rating Scale						
Hydrotherapy group	3.95±1.31	$0.95 \pm 1.27$	$0.00 \pm 0.00$			
Convention group	4.10±1.71	$1.20 \pm 1.32$	$0.08 \pm 0.45$			
Passive range of motion of knee flexion (degrees)						
Flexion						
Hydrotherapy group	99.21±6.51	112.21±6.55	118.16±5.33			
Convention group	95.10±12.31	108.16±8.76	113.06±7.76			
Extension						
Hydrotherapy group	$2.11 \pm 3.04$	0.26±1.15	$0.26 \pm 1.15$			
Convention group	$4.29 \pm 5.40$	2.14±3.06	$1.43 \pm 2.70$			
Self-reported walking tolerance (minutes)						

 Table 3
 Longitudinal comparisons of outcomes in Hydrotherapy group and Convention group

 $5.26 \pm 1.15$ 

5.61±2.63

 $40.58 \pm 10.43$ 

 $50.49 \pm 20.98$ 

 $1.74 \pm 2.51$ 

 $1.90 \pm 2.82$ 

Convention group
\* Statistical significance (P<0.05)

Hydrotherapy group

Hydrotherapy group

Hydrotherapy group

Convention group

Timed Up and Go Test (seconds)

30-s Chair Stand Test (repetitions)

Convention group



\* p < 0.001

# # p < 0.05

Fig. 5 Longitudinal changes of Knee Society Function score (KFS) in Hydrotherapy group and Convention group, \* P<0.001, # P<0.05

in pain levels did not reach statistical significance, and (3) initiation of hydrotherapy days after surgery. The only difference is UKA vs. TKA. This is still worth further exploring the application of hydrotherapy on patients after UKA, although the percentages of patients receiving UKA remained stable, staying at 5-8% of all primary knee joint arthroplasties in the UK, substantially dependent on geographic location [2] [23]. In summary, patients who underwent UKA experienced similar advantages to those receiving TKA, with the added benefits of UKA being less invasive, requiring shorter hospital stays, and allowing for faster rehabilitation. Further randomized controlled trials or large-scale cohort studies are recommended to consolidate these observations. The results from this feasibility study provided a solid foundation for promoting further research on the application of hydrotherapy for post-UKA patients.

NPRS, TUGT, and 30CST did not show any statistical difference after adding hydrotherapy to conventional rehabilitation program. Other synthesized findings from previously cited systematic reviews and meta-analysis did not demonstrate improvements in pain and physical activity [20]. Similar results were also reported elsewhere [21]. TUGT is a sensitive and specific outcome measure primarily for determining fall risk in the elderly, also measuring balance performance [24]. TUGT cut-off of fall risk for community-dwelling elderly is 13.5 s [24], meaning that any performance of TUGT recorded longer than 13.5 s is classified as a relatively higher risk of fall, which needs follow-up assessment and management for fall prevention [24, 25]. TUGT from both groups in this study was lower than the cut-off. 30CST is a reliable outcome metric measuring muscle strength of lower limbs in elderly through performing a functional performancebased task [26]. Normative means of 30CST in the age group of 70 to 74 years (mean age in our study=69.24) are 10.1 repetitions (female) and 11.6 repetitions (male) [27]. The mean 30CST values from our two groups were close to the normative means. Consequently, muscle strength improvements of lower limbs in patients after UKA patients after hydrotherapy resembles the effects after conventional exercises.

Several limitations of this study need to be considered. First, it was a retrospective study and selection bias could not be ruled out. Second, the small number of subjects may limit the data generalizability of this study. Third, self-reported walking tolerance, TUGT, and 30CST were not collected at postoperative 4 weeks because we aimed at comparing the data in the first and last sessions in the first place. Fourth, preoperative flexion and extension ROM was not extracted from the clinical electronic system (preoperative ROM was routinely measured as a clinic practice and the data were stored in the system) because extra resource was required to extract the data. These variables will be added to the data collection plan in further studies. Fifth, the inclusion criteria of patients receiving primary unilateral UKA with the model of Oxford® Partial Knee (Zimmer Biomet, UK) may also limit the application of research findings. This feasibility study is the first step to the further research on the effect of hydrotherapy on patients who underwent UKA. Follow-up study to support the existing findings is highly recommended. Results of this study provide insights for future studies on the effects of hydrotherapy on patients having bilateral UKA or the clinical outcomes of integrating hydrotherapy into rehabilitation. Furthermore, a randomized controlled trial with a larger sample size and similar number of subjects on each group could be another step forward.

# Conclusion

This feasibility study examined the effect of hydrotherapy on post-UKA patients. Patients who underwent UKA after hydrotherapy showed significant improvements in function and range of motion, both in flexion and extension. Additionally, walking tolerance significantly improved after completing the program. Pain, mobility, balance, and leg strength and endurance were comparable between patients with or without additional hydrotherapy, in combination with conventional physiotherapy. Since this was the first study of its kind, further research with advanced study design, larger sample size, and longer follow-up periods for patients who underwent UKA is recommended.

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#### Authors' contributions

M.Y.L. and K.K.W.H. conceptualized the research. K.K.W.H., T.L.C., G.Y.T.L., and M.T.Y.O. performed the clinical examination and surgery on patients. M.Y.L. conducted the literature search, assessed patients, and carried out data collection, data extraction, data synthesis, and data integration. W.W.C. and M.Y.L. performed data analysis. W.W.C. and M.Y.L. drafted and revised the important intellectual content of the manuscript. All authors reviewed, revised, and approved the final version of this manuscript.

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#### Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon request.

#### Declarations

#### Ethics approval and consent to participate

Ethical approval was obtained from the ethics review board of the Joint Chinese University of Hong Kong—New Territories East Cluster Clinical Research Ethics Committee (Ref. No.: CRE2020.586). The study protocol complied with the Declaration of Helsinki. Informed consent has been obtained from all participants.

#### **Consent for publication**

Not Applicable.

#### **Competing interests**

The authors declare that they have no competing interests.

#### Author details

<sup>1</sup>Department of Orthopaedics and Traumatology, Chinese University of Hong Kong, Hong Kong SAR, China. <sup>2</sup>Department of Orthopaedics and Traumatology, Alice Ho Miu Ling Nethersole Hospital, Hong Kong SAR, China.

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