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Research Article

The effect of 8 weeks of hydrotherapy and land-based exercises on strength, balance, range of motion and pain reduction in elderly women with history of both knees' replacement

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Abstract

Introduction: Exercise program after knee replacement surgery improves postoperative pain, length of hospital stays, and health-related quality of life. However, the effectiveness of postoperative interventions has been different with the type of intervention protocols. The main purpose of this study was to investigate the effect of 8 weeks hydrotherapy and land based exercise on strength, balance, range of motion and pain reduction in elderly women with history of both knees replacement.

Methods: In this semi-experimental study, 30 elderly women with history of both knees replacement from Tehran were selected and randomly divided into three groups: land exercise, hydrotherapy exercise and control. The training program consisted of three sessions per week, each session lasting 60 minutes, including flexibility exercise, movement coordination and agility, balance exercise (perception of space, time and reaction speed) and strength exercise for eight weeks on land and water. The subjects were tested for strength, balance, range of motion and pain level before and after the training. To compare the results of the groups, were used one-way analysis of variance and Tukey's post hoc test at the $P<0.05$.

Results: The results showed that eight weeks of hydrotherapy and land based exercise have significant effect on strength, balance, range of motion and the amount of pain reduction in elderly women with history of both knees replacement ($p=0.001$), but there was no significant difference between changes in strength, balance, range of motion and pain reduction between the two experimental groups ($P<0.05$).

Conclusion: According to the results, it is possible to recommend hydrotherapy and land based exercise interventions to improve strength, balance, range of motion and reduce pain in patients with history of both knees replacement.

Keywords:
Hydrotherapy and Land training, Range of motion, Pain, Knee replacement synaptic transmission.

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Introduction

Osteoarthritis, due to a significant reduction in muscle strength and flexibility, along with knee joint pain, is the most common cause of disability among the elderly (1). When conservative treatments fail, knee replacement surgery is prescribed as a surgical alternative for patients with osteoarthritis to replace the degenerated or deformed joint (2, 3). Knee replacement involves the artificial replacement of the damaged or ankylosed joint. The knee joint functions as a complex hinge, allowing flexion, extension, rotation, and gliding. The knee joint itself consists of three parts: lateral, medial, and patellofemoral. Disease processes that damage the cartilage in one or all three compartments may lead to the need for total knee replacement. Examples of such diseases include osteoarthritis (idiopathic or traumatic), inflammatory arthritis (e.g., rheumatoid, psoriatic), avascular necrosis, tumors, and congenital abnormalities. The primary diagnoses typically associated with knee replacement procedures are osteoarthritis and related disorders (90.9%), followed by rheumatoid arthritis and other inflammatory polyarthropathies (3.4%) (4).

Knee replacement is a widely performed procedure for advanced knee arthropathies. It consistently reduces pain, improves function, and enhances quality of life (5). With the aging population and the increasing prevalence of this procedure, it is predicted that a growing number of patients will undergo knee replacement. The most common age group for total knee replacement is 65 to 84 years. Women in this age range are more likely to undergo knee replacement than their male counterparts. Despite the documented success of this procedure, patients continue to exhibit functional, strength, and mobility deficits after knee replacement (7).

Although knee replacement improves self-reported functional ability and reduces pain, it does not eliminate all impairments compared to age-matched individuals without knee pathology (7).

Rehabilitation, with an emphasis on exercise, is widely recommended after knee replacement. Exercise plays a crucial role in optimal rehabilitation following knee replacement. Exercise may include strength, endurance, flexibility, and balance training aimed at correcting deficiencies, restoring muscle strength and joint range of motion (ROM), and ultimately improving physical health and restoring normal function (8). Exercise targets achieving functional goals and is associated with patient satisfaction and improved function. However, rehabilitation programs vary in terms of the type and duration of exercises (9, 10). Some studies have examined the effects of postoperative exercise on body function in patients with knee replacement. In this context, patients who participated in exercise following knee replacement had better postoperative knee scores, balance, range of motion, quality of life, and lower body mass index compared to inactive patients (11-13). Pietschmann et al. (2013) found that active patients experienced less pain after surgery (14), although some studies have not reported such a relationship between pain reduction and exercise activities (15, 16). Minns Lowe et al. (2007) also investigated the effects of postoperative exercise in knee replacement patients and found no significant effects on walking or quality of life, although knee range of motion significantly improved compared to the control group (17). On the other hand, based on the results of Ghiami Rad et al. (1400), hydrotherapy can be used as a beneficial method for rehabilitating elderly women after knee replacement (18). The results of Catalin et al. (2019)

showed that patients who underwent knee replacement surgery and aquatic exercise had higher scores in the range of motion index compared to those who performed land-based exercises (19). Zhuo et al. (2021) also found that patients with knee replacement who used hydrotherapy experienced greater improvement in muscle strength compared to walking speed (20).

Persistent functional deficits and muscle impairments after knee replacement may be partly attributed to the lack of appropriate rehabilitation and exercise programs post-surgery. Currently, there is no universally accepted rehabilitation protocol for patients after knee replacement, and rehabilitation methods are often specific to an institution or surgeon. Recent evidence suggests that the type of postoperative rehabilitation affects short- and long-term functional outcomes. The effect of hydrotherapy and land-based exercises on strength, balance, range of motion, and pain reduction in elderly individuals with a history of knee replacement remains unclear for achieving positive outcomes. This is because previous studies have yielded conflicting results. Additionally, it is unclear which intervention is better for improving strength, balance, range of motion, and pain reduction in elderly women with a history of bilateral knee replacement, as there is significant variability in the parameters evaluated. Further research is needed to identify optimal stimulation targets for strength, balance, range of motion, and pain reduction in hydrotherapy and land-based exercise interventions. Therefore, this study aims to address the question: Does eight weeks of hydrotherapy and land-based exercise affect strength, balance, range of motion, and pain reduction in elderly women with a history of both knee replacement?

Methods

The present study is applied research with a quasi-experimental design, conducted as a pre-test/post-test study. The statistical population consisted of all elderly women with a history of both knee replacement in Tehran (Tehranpars Hospital). The sample size for the current study was determined based on previous research results, with a significance level of 5% (Type I error) and a statistical power of 95% (Type II error), using Medcalc 18.2.1 software (10 participants per group). Inclusion criteria included: elderly women with a history of bilateral knee replacement, aged 55 to 65 years, female gender, no other problems or surgeries in the lower limbs except knee replacement that would limit function, no cognitive impairment, no planned surgeries during the study period, no postoperative complications such as hemarthrosis, infection, fracture, or wound disorder, and willingness to participate in the study. Exclusion criteria included the occurrence of deep vein thrombosis, any issues during the exercise program, lack of willingness to continue cooperation, and absence from more than three exercise sessions. Before the study began, all necessary coordination with the pool for conducting tests and exercises was completed. All eligible participants submitted written consent forms and relevant questionnaires one week before the study began and expressed their readiness to start the exercise interventions. An orientation session was held with the researcher to familiarize participants with the study procedure, the schedule for the protocol, and other explanations. Height and weight were measured and recorded using a Seca scale and stadiometer. Then, strength, balance, range of motion, and pain reduction tests were conducted. Participants were then divided into three groups: control, land-based exercise, and aquatic exercise.

The experimental groups performed the exercises for eight weeks. After the exercise program, post-tests were conducted on the participants.

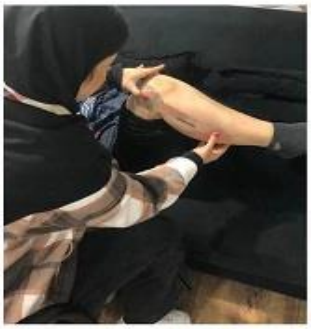
Dynamic Balance Assessment

Static Balance Assessment

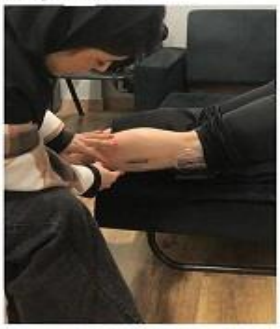
(Stabilometer)

Isometric Strength Dynamometer

(Hamstring Strength)



Knee Flexion (ROM)



Knee Extention (ROM)

Measurement Tools

To measure balance, the Biodex Balance System SD (manufactured by Biodex, USA) was used. This device was employed to calculate dynamic balance on 12 stability levels and to analyze static balance on a fixed platform. To minimize errors, the device was calibrated before and after each measurement (21). For strength measurement, an isometric leg strength dynamometer (model BL250 A1, manufactured in Iran) was used to assess isometric strength (both training and testing). To measure static range of motion, a digital goniometer made in Germany was used. Additionally, to evaluate pain levels the Visual Analog Scale (VAS) was used, which is a 10-point scale (where 0 indicates no pain and 10 indicates the worst imaginable pain) (Figure 1) (22).

Exercise Protocol (Land and Water)

The exercise protocol in this study consisted of eight weeks of hydrotherapy and land-based exercises, conducted under the supervision of a trainer and researcher. The hydrotherapy exercises were performed in a therapeutic pool with water temperature set between 31-32°C. Participants engaged in three sessions per week, with each session including 5 minutes of warm-up, 50 minutes of exercise (performed in various sets with rest intervals between sets, and the training load increased alternately each week), and 5 minutes of cool-down. Land-based exercises were conducted on the poolside in a safe area covered with 2.5 cm thick tatami mats (23).

Statistical Analysis

The Shapiro-Wilk test was used to determine the normality of the data distribution. Then, a one-way analysis of variance (ANOVA) and Tukey's post hoc test were used to compare the groups. Calculations were performed using SPSS software (version 26), and the significance level for the tests was set at $p \leq 0.05$.

Results

Table 1 presents the descriptive results of the research variables across the different groups.

Table 1: Descriptive Results of Research Variables Across Groups

Variable	Hydrotherapy (Pre-test)	Hydrotherapy (Post-test)	Land-Based Exercise (Pre-test)	Land-Based Exercise (Post-test)	Control (Pre-test)	Control (Post-test)
Strength	16.69 ± 1.32	21.36 ± 1.43	16.44 ± 1.08	21.09 ± 1.10	16.74 ± 0.92	16.64 ± 1.14
Flexion	99.40 ± 2.83	116.20 ± 2.48	101.00 ± 2.30	116.50 ± 1.35	99.40 ± 2.36	99.90 ± 2.99
Extension	5.82 ± 0.39	1.31 ± 0.18	5.92 ± 0.45	1.39 ± 0.13	5.77 ± 0.18	4.08 ± 0.25
Static Balance	0.74 ± 0.04	0.44 ± 0.04	0.75 ± 0.04	0.45 ± 0.03	0.72 ± 0.02	0.71 ± 0.02
Dynamic Balance	1.80 ± 0.03	1.26 ± 0.07	1.80 ± 0.04	1.26 ± 0.08	1.80 ± 0.00	1.80 ± 0.01
Pain Intensity	6.50 ± 1.26	2.90 ± 1.10	6.10 ± 1.10	3.10 ± 1.10	6.10 ± 1.10	6.30 ± 1.05

Statistical Findings

The results of the one-way ANOVA showed that eight weeks of hydrotherapy and land-based exercises had a significant effect on strength in elderly women with a history of both knee replacement ($p = 0.001$). Tukey's post hoc test revealed a significant difference between the hydrotherapy group and the land-based exercise group compared to the control group ($p = 0.001$), but there was no significant difference between the two experimental groups ($p = 0.995$).

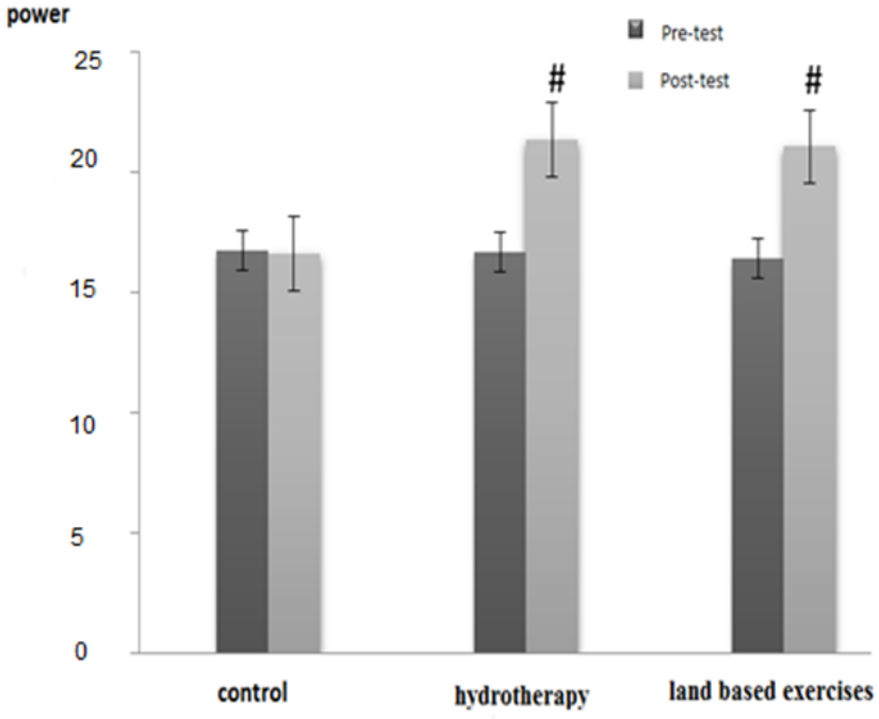


Figure 1. Changes in Strength in Elderly Women with a History of Both Knee Replacement Across Different Study Groups

Results of Statistical Analysis

The results of the one-way ANOVA showed that eight weeks of hydrotherapy and land-based exercises had a significant effect on knee flexion in elderly women with a history of both knee replacement ($p = 0.001$). Tukey's post hoc test revealed a significant difference between the hydrotherapy group and the land-based exercise group compared to the control group ($p = 0.001$). However, there was no significant difference between the two experimental groups ($p = 0.385$).

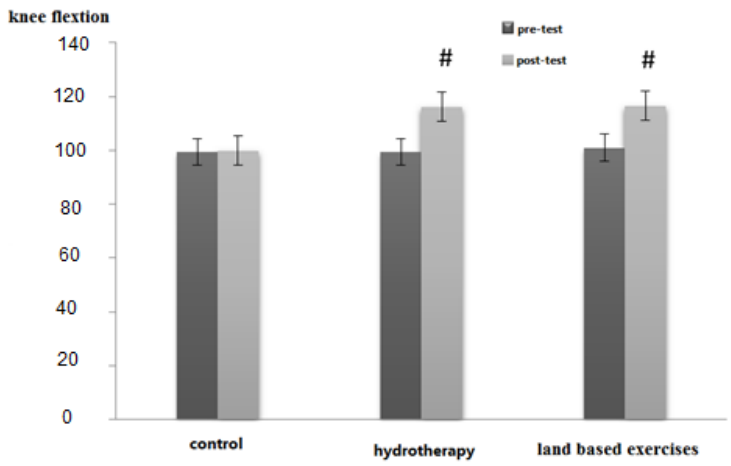


Figure 2. Changes in Strength in Elderly Women with a History of Both Knee Replacement Across Different Study Groups

Results of Statistical Analysis

The results of the one-way ANOVA showed that eight weeks of hydrotherapy and land-based exercises had a significant effect on knee extension in elderly women with a history of both knee replacement ($p = 0.001$). Tukey's post hoc test revealed a significant difference between the hydrotherapy group and the land-based exercise group compared to the control group ($p = 0.001$). However, there was no significant difference between the two experimental groups ($p = 0.992$).

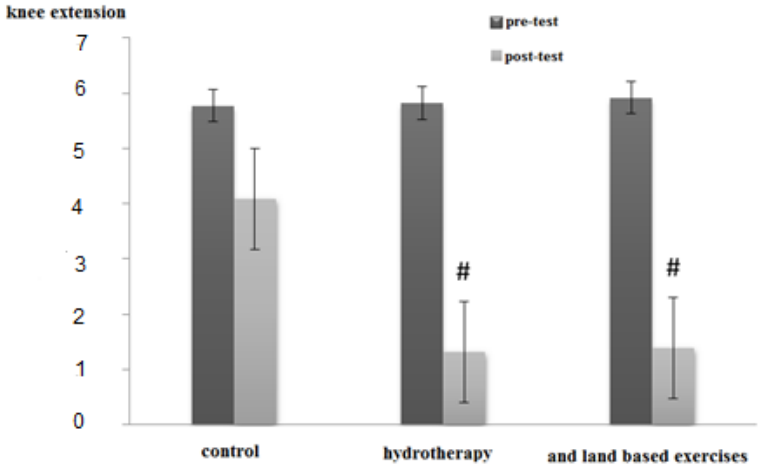


Figure 3. Changes in Knee Extension in Elderly Women with a History of Both Knee Replacement Across Different Study Groups

Results of Statistical Analysis

The results of the one-way ANOVA showed that eight weeks of hydrotherapy and land-based exercises had a significant effect on static balance in elderly women with a history of both knee replacement ($p = 0.001$). Tukey's post hoc test revealed a significant difference between the hydrotherapy group and the land-based exercise group compared to the control group ($p = 0.001$). However, there was no significant difference between the two experimental groups ($p = 0.858$).

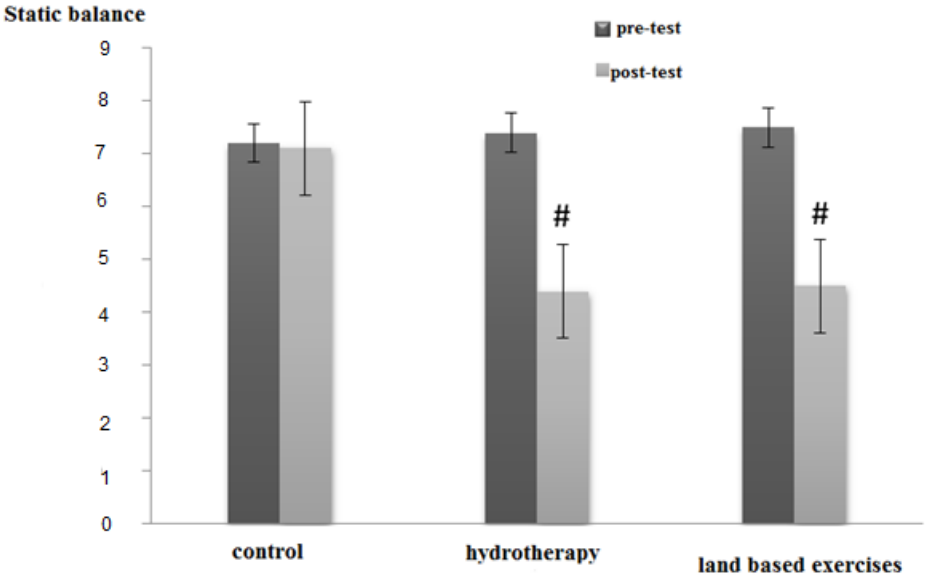


Figure 4. Changes in Static Balance in Elderly Women with a History of Both Knee Replacement Across Different Study Groups

Results of Statistical Analysis

The results of the one-way ANOVA showed that eight weeks of hydrotherapy and land-based exercises had a significant effect on dynamic balance in elderly women with a history of both knee replacement ($p = 0.001$). Tukey's post hoc test revealed a significant difference between the hydrotherapy group and the land-based exercise group compared to the control group ($p = 0.001$). However, there was no significant difference between the two experimental groups ($p = 0.996$).

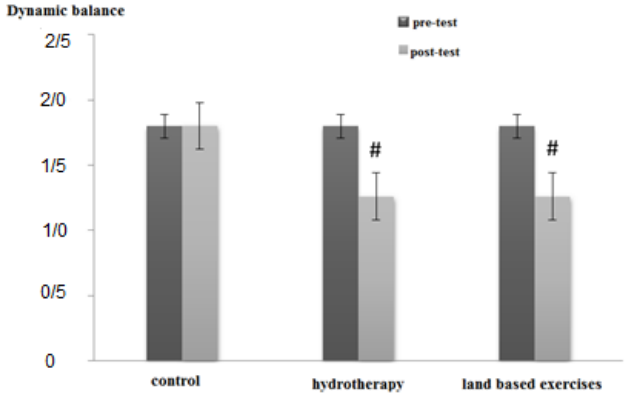


Figure 5. Changes in Dynamic Balance in Elderly Women with a History of Both Knee Replacement Across Different Study Groups

Results of Statistical Analysis

The results of the one-way ANOVA showed that eight weeks of hydrotherapy and land-based exercises had a significant effect on pain intensity in elderly women with a history of both knee replacement ($p = 0.001$). Tukey's post hoc test revealed a significant difference between the hydrotherapy group and the land-based exercise group compared to the control group ($p = 0.001$). However, there was no significant difference between the two experimental groups ($p = 0.169$).

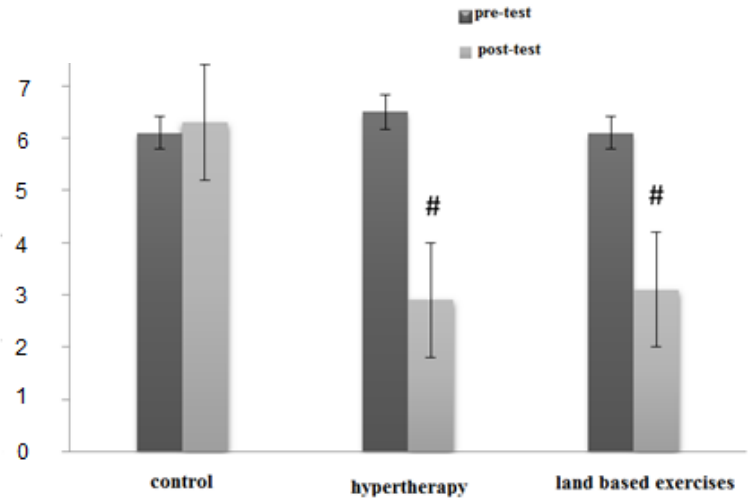


Figure 6. Changes in Pain Intensity in Elderly Women with a History of Both Knee Replacement Across Different Study Groups

Discussion

The results of the present study indicate that eight weeks of hydrotherapy and land-based exercises led to improvements in strength, balance, range of motion, and pain reduction in elderly women with a history of both knee replacement. These findings are consistent with the results of studies by Tilp et al. (2023), Moaref Khanli et al. (1399), Yousefian et al. (1392), Rak et al. (2022), and Ghiami Rad et al. (1400) (11, 12, 18, 24, 25). Additionally, the findings align with those of Zhuo et al. (2021), who conducted a review study on hydrotherapy interventions for patients with knee replacement and found that individuals who used hydrotherapy experienced significant improvements in muscle strength (20).

With aging, especially after the age of 60, muscle strength and size tend to decline. However, through exercise, elderly individuals can significantly enhance their muscle strength and

with no significant difference observed between the two methods in terms of strength improvement.

Based on the findings of this study, it seems that hydrotherapy and land-based exercises can be useful methods for rehabilitating range of motion (flexion and extension) in elderly women after knee replacement. The primary goals of rehabilitation after knee replacement are early restoration of range of motion (ROM) and patient mobility. Range of motion is a key indicator of successful knee replacement and is directly related to function (28). Adequate knee flexion of 90-120 degrees is necessary for daily activities such as transitioning from sitting to standing and climbing stairs (29).

When elderly individuals lose their balance, the recovery process often differs from that of younger adults' endurance. These improvements are associated with an increase in muscle cross-sectional area and the number of muscle fibers. Furthermore, post-knee replacement functional improvement is largely attributed to the recovery of the knee extensor mechanism. Following knee replacement, weakness in the quadriceps and hamstring muscles can persist for up to two years, leading to difficulties in daily activities such as climbing stairs or walking (26). However, achieving postoperative improvement in the quadriceps and hamstring muscles can be multifactorial. Factors such as age, body mass index (BMI), and the type of exercise may play a role (27). Although muscle size and strength tend to decline with aging, appropriate exercise can slow or even reverse this process. It appears that both exercise protocols (hydrotherapy and land-based) can be used successfully to restore knee strength after total knee arthroplasty (TKA),

However, limitations of the study include the small sample size in each group, which prevents a more detailed analysis of factors such as gender, age, type of surgery, or time since surgery. Additionally, the rehabilitation period was limited to eight weeks due to existing constraints, and the results may differ for shorter or longer rehabilitation periods in other countries. These limitations should be considered in future studies. Furthermore, muscle recruitment and hypertrophy around the knee were not measured, and it is suggested that similar studies be conducted on women with these indicators

The negative impact of pain on rehabilitation delays and disrupts the recovery of function, muscle strength, and return to normal activities. Additionally, pain after TKR, compared to THR, takes longer to improve and return to activity, lasting about 50 days. Therefore, pain control in knee arthroplasty is more important than in hip arthroplasty due to its impact on improving range of motion and muscle strength.

The results of our study are inconsistent with the findings of Zaghloul et al. (2020) and Catalin et al. (2019), where the experimental and control groups reported similar pain intensity scores after total knee replacement and intervention periods (19, 36). Differences in participants (healthy individuals vs. TKR patients), muscles trained (quadriceps vs. ankle extensors), unilateral training, duration and repetition of training (3 weeks vs. several months), and the intensity and type of contraction (concentric, eccentric, isometric) during training may contribute to observable differences in outcomes.

Although further research is needed on the effects of hydrotherapy and land-based exercises on strength, balance, range of motion, and pain reduction in elderly women with a history of both knee replacement, the results of this study suggest that both hydrotherapy and land-based exercises can be beneficial in improving these indicators. Therefore, it is recommended that physicians, physiotherapists, and sports science specialists use both types of exercises to improve strength, balance, range of motion, and pain reduction in elderly individuals with a history of bilateral knee replacement. This study included objective measurements to evaluate the effects of hydrotherapy and land-based exercises. Another strength of this study is its direct application in a rehabilitation setting.

and is less effective. One difference in this age group is the timing of muscle activation. When a person standing upright loses balance and begins to lean backward, the recovery process typically involves activating the ankle flexors followed by the knee extensors. However, some elderly individuals exhibit a reversed muscle activation pattern in their attempt to regain balance (31).

Knee pain and quadriceps weakness are associated with increased postural sway. Studies show that patients undergoing knee replacement often experience significant deficits in balance control and proprioceptive acuity, often due to a lack of confidence (32). It is expected that the incidence of falls as a clinical outcome of knee replacement will decrease with reduced pain, satisfactory function, and improved proprioception during the postoperative period (33). In contrast, some studies have shown that sacrificing the anterior cruciate ligament leads to proprioceptive/balance deficits after knee replacement, thereby increasing the risk of falls (34). However, few studies have examined the clinical outcomes related to changes in trunk position and static and dynamic balance issues in the early postoperative period after knee replacement (30).

In fact, more than 50% of patients undergoing this surgery report severe and significant postoperative pain, with total knee replacement (TKR) patients experiencing more pain than total hip replacement (THR) patients. Some reasons for persistent postoperative pain include infection, improper mechanical component function, sympathetic pain syndromes, nerve entrapment, and musculoskeletal pain. Hoffman's algorithm, which investigates the causes of pain after total knee replacement, lists musculoskeletal or extra-articular pain as the tenth skeletal cause of pain (35).

Conclusion

In summary, the results of this study demonstrate that eight weeks of hydrotherapy and land-based exercises are effective in improving strength, balance, range of motion, and pain reduction in elderly women with a history of both knee replacement. Both interventions can be specifically recommended for patients with a history of bilateral knee replacement. However, further research on these exercises is needed.

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Compliance with ethical standards

Conflict of interest None declared.

Ethical approval the research was conducted with regard to the ethical principles.

Informed consent Informed consent was obtained from all participants.

References

1. Brown K, Kachelman J, Topp R, Quesada PM, Nyland J, Malkani A, Swank AM. Predictors of functional task performance among patients scheduled for total knee arthroplasty. J Strength Cond Res. 2009 Mar;23(2):436-43. doi: 10.1519/JSC.0b013e318198fc13. PMID: 19197199.

2. Qiao Y, Li F, Zhang L, Song X, Yu X, Zhang H, Liu P, Zhou S. A systematic review and meta-analysis comparing outcomes following total knee arthroplasty for rheumatoid arthritis versus for osteoarthritis. BMC Musculoskelet Disord. 2023 Jun 13;24(1):484. doi: 10.1186/s12891-023-06601-9. PMID: 37312069; PMCID: PMC10262433.

3. Takeda R, Matsumoto T, Omata Y, Inui H, Taketomi S, Nagase Y, Nishikawa T, Oka H, Tanaka S. Changes in knee joint destruction patterns among patients with rheumatoid arthritis undergoing total knee arthroplasty in recent decades. Clin Rheumatol. 2023 Sep;42(9):2341-2352. doi: 10.1007/s10067-023-06620-w. Epub 2023 May 24. PMID: 37222908; PMCID: PMC10412667.

4. Mihalko WM. Arthroplasty of the knee. In: Azar FM, Beaty JH, eds. Campbell's Operative Orthopaedics.14th ed. Philadelphia, PA: Elsevier; 2021: chap 7.

5. Stilling M, Mechlenburg I, Jepsen CF, Rømer L, Rahbek O, Søballe K, Madsen F. Superior fixation and less periprosthetic stress-shielding of tibial components with a finned stem versus an I-beam block stem: a randomized RSA and DXA study with minimum 5 years' follow-up. Acta Orthop. 2019 Apr;90(2):165-171. doi: 10.1080/17453674.2019.1566510. Epub 2019 Jan 23. PMID: 30669918; PMCID: PMC6461099.

6. Kishor Gandhi MD, MPH and Eugen Viscusi MD, Multimodal pain Management Technique in Hip and Knee Arthroplasty, Thomas Jefferson University, Philadelphia, PA. the Journal of new York School of- Regional Anesthesia July 2009 VOL.13

7. Ravi B, Croxford R, Reichmann WM, Losina E, Katz JN, Hawker GA. The changing demographics of total joint arthroplasty recipients in the United States and Ontario from 2001 to 2007. Best Pract Res Clin Rheumatol. 2012 Oct;26(5):637-47. doi: 10.1016/j.berh.2012.07.014. PMID: 23218428.

8. Kisner C, Colby LA, Borstad J. Therapeutic Exercise. Foundations and Techniques (7th ed.). F.A. Davis Company; 2017

9. Oatis CA, Li W, DiRusso JM, Hoover MJ, Johnston KK, Butz MK, Phillips AL, Nanovic KM, Cummings EC, Rosal MC, Ayers DC, Franklin PD. Variations in Delivery and Exercise Content of Physical Therapy Rehabilitation Following Total Knee Replacement Surgery: A Cross-Sectional Observation Study. Int J Phys Med Rehabil. 2014;Suppl 5:002. doi: 10.4172/2329-9096.S5-002. Epub 2014 Apr 22. PMID: 26594649; PMCID: PMC4651458.

10. Artz N, Dixon S, Wylde V, Beswick A, Blom A, Gooberman-Hill R. Physiotherapy provision following discharge after total hip and total knee replacement: a survey of current practice at high-volume NHS hospitals in England and wales. Musculoskeletal Care. 2013 Mar;11(1):31-8. doi: 10.1002/msc.1027. Epub 2012 Jul 9. PMID: 22778023.

11. Moaref Khanli M, Akbari M, Amiri A. The Effect of Early Hip-strengthening on Physical Function in Patients With Unilateral Total Knee Arthroplasty. J Arak Uni Med Sci 2020; 23 (6) :912-925.

12. Yousefian Molla Razieh, Sadeghi Haider, Jameh Gehrir Ali Asghar, Kohlai Amirhossein. Evaluation of the balance of elderly patients with knee arthritis before and after knee joint replacement surgery. International Conference on Physical Education and Sports. 2012.

13. Vielgut I, Leitner L, Kastner N, Radl R, Leithner A, Sadoghi P. Sports Activity after Low-contact-stress Total Knee Arthroplasty - A long term follow-up study. Sci Rep. 2016 Apr 19;6:24630. doi: 10.1038/srep24630. PMID: 27090945; PMCID: PMC4835733.

14. Pietschmann MF, Wohlleb L, Weber P, Schmidutz F, Ficklscherer A, Gülecyüz MF, Safi E, Niethammer TR, Jansson V, Müller PE. Sports activities after medial unicompartmental knee arthroplasty Oxford III-what can we expect? Int Orthop. 2013 Jan;37(1):31-7. doi: 10.1007/s00264-012-1710-7. Epub 2012 Nov 23. PMID: 23180099; PMCID: PMC3532643.

15. Chang MJ, Kim SH, Kang YG, Chang CB, Kim TK. Activity levels and participation in physical activities by Korean patients following total knee arthroplasty. BMC Musculoskelet Disord. 2014 Jul 17;15:240. doi: 10.1186/1471-2474-15-240. PMID: 25030804; PMCID: PMC4108970.

16. Liu, Shi-chen MMa; Hou, Zhi-ling MMb; Tang, Qing-xi MMb; Qiao, Xiao-feng MMa; Yang, Jian-hua MDc; Ji, Qing-hui MMa,*. Effect of knee joint function training on joint functional rehabilitation after knee replacement. Medicine 97(28):p e11270, July 2018.

17. Minns Lowe CJ, Barker KL, Dewey M, Sackley CM. Effectiveness of physiotherapy exercise after knee arthroplasty for osteoarthritis: systematic review and meta-analysis of randomised controlled trials. BMJ. 2007 Oct 20;335(7624):812. doi: 10.1136/bmj.39311.460093.BE. Epub 2007 Sep 20. PMID: 17884861; PMCID: PMC2034713.

18. Ghiami Rad A, Hassan Pour V, Hatemlu H. The Effects of Hydrotherapy on Pain, Range of Motion, and Quality of Life After Joint Replacement in the Elderly Women With Knee Arthritis.

19. Catalin N, Nicolae N, Margit SV. EFFECTIVENESS OF AQUATIC PHYSICAL THERAPY VS. LAND-BASED PHYSICAL THERAPY IN PATIENTS WHICH UNDERWENT KNEE REPLACEMENT SURGERY. Acta Medica Marisiensis. 2019;65

20. Zhuo Y, Yu R, Wu C, Zhang Y. Hydrotherapy Intervention for Patients Following Total Knee Arthroplasty: A Systematic Review. Physikalische Medizin, Rehabilitationsmedizin, Kurortmedizin. 2021;31(03):6-170

21. Santos SM, da Silva RA, Terra MB, Almeida IA, de Melo LB, Ferraz HB. Balance versus resistance training on postural control in patients with Parkinson's disease: a randomized controlled trial. Eur J Phys Rehabil Med. 2017 Apr;53(2):173-183. doi: 10.23736/S1973-9087.16.04313-6. Epub 2016 Nov 23. PMID: 27879959.

22. Doerfler D, Gurney B, Mermier C, Rauh M, Black L, Andrews R. High-Velocity Quadriceps Exercises Compared to Slow-Velocity Quadriceps Exercises Following Total Knee Arthroplasty: A Randomized Clinical Study. J Geriatr Phys Ther. 2016 Oct-Dec;39(4):147-58. doi: 10.1519/JPT.0000000000000071. PMID: 26428903.

23. Alcalde GE, Fonseca AC, Bôscoa TF, Gonçalves MR, Bernardo GC, Pianna B, Carnavale BF, Gimenes C, Barrile SR, Arca EA. Effect of aquatic physical therapy on pain perception, functional capacity and quality of life in older people with knee osteoarthritis: study protocol for a randomized controlled trial. Trials. 2017 Jul 11;18(1):317. doi: 10.1186/s13063-017-2061-x. PMID: 28697785; PMCID: PMC5504767.

24. Rak D, Nedopil AJ, Sayre EC, Masri BA, Rudert M. Postoperative Inpatient Rehabilitation Does Not Increase Knee Function after Primary Total Knee Arthroplasty. J Pers Med. 2022 Nov 21;12(11):1934. doi: 10.3390/jpm12111934. PMID: 36422110; PMCID: PMC9697033.

25. Tilp M, Ringler S, Mariacher H, Rafolt D. Unilateral Strength Training after Total Knee Arthroplasty Leads to Similar or Better Effects on Strength and Flexibility than Bilateral Strength Training - A Randomized Controlled Pilot Study. J Rehabil Med. 2023 Apr 19;55:jrm00381. doi: 10.2340/jrm.v55.3987. PMID: 37073719; PMCID: PMC10161435.

26. Bjerke J, Öhberg F, Nilsson KG, Foss OA, Stensdotter AK. Peak knee flexion angles during stair descent in TKA patients. J Arthroplasty. 2014 Apr;29(4):707-11. doi: 10.1016/j.arth.2013.07.010. Epub 2013 Aug 9. PMID: 23937925.

27. Jo AR, Song EK, Lee KB, Seo HY, Kim SK, Seon JK. A comparison of stability and clinical outcomes in single-radius versus multi-radius femoral design for total knee arthroplasty. J Arthroplasty. 2014 Dec;29(12):2402-6. doi: 10.1016/j.arth.2014.03.033. Epub 2014 Mar 31. PMID: 24793892.

28. Harvey LA, Brosseau L, Herbert RD. Continuous passive motion following total knee arthroplasty in people with arthritis. Cochrane Database Syst Rev. 2014 Feb 6;2014(2):CD004260. doi: 10.1002/14651858.CD004260.pub3. PMID: 24500904; PMCID: PMC10646823.

29. Rowe PJ, Myles CM, Walker C, Nutton R. Knee joint kinematics in gait and other functional activities measured using flexible electrogoniometry: how much knee motion is sufficient for normal daily life? Gait Posture. 2000 Oct;12(2):143-55. doi: 10.1016/s0966-6362(00)00060-6. PMID: 10998612.

30. Schwartz I, Kandel L, Sajina A, Litinezki D, Herman A, Mattan Y. Balance is an important predictive factor for quality of life and function after primary total knee replacement. J Bone Joint Surg Br. 2012 Jun;94(6):782-6. doi: 10.1302/0301-620X.94B6.27874. PMID: 22628592.

31. Cammarata ML, Schnitzer TJ, Dhaher YY. Does knee osteoarthritis differentially modulate proprioceptive acuity in the frontal and sagittal planes of the knee? Arthritis Rheum. 2011 Sep;63(9):2681-9. doi: 10.1002/art.30436. PMID: 21547895; PMCID: PMC3641758.

32. Duffell LD, Southgate DF, Gulati V, McGregor AH. Balance and gait adaptations in patients with early knee osteoarthritis. Gait Posture. 2014 Apr;39(4):1057-61. doi: 10.1016/j.gaitpost.2014.01.005. Epub 2014 Jan 19. PMID: 24582072; PMCID: PMC3989045.

33. Hernefalk B, Brüggemann A, Mohammed J, Mukka S, Wolf O. Lower mortality in distal femoral fractures in the presence of a knee arthroplasty: an observational study on 2,725 fractures from the Swedish Fracture Register. Acta Orthop. 2022 Jul 22;93:684-688. doi: 10.2340/17453674.2022.4376. PMID: 35866693; PMCID: PMC9306289.

33. Gage WH, Frank JS, Prentice SD, Stevenson P. Postural responses following a rotational support surface perturbation, following knee joint replacement: frontal plane rotations. Gait Posture. 2008 Feb;27(2):286-93. doi: 10.1016/j.gaitpost.2007.04.006. Epub 2007 May 17. PMID: 17499994.

34. Gage WH, Frank JS, Prentice SD, Stevenson P. Postural responses following a rotational support surface perturbation, following knee joint replacement: frontal plane rotations. Gait Posture. 2008 Feb;27(2):286-93. doi: 10.1016/j.gaitpost.2007.04.006. Epub 2007 May 17. PMID: 17499994.

35. Hofmann S, Seitlinger G, Djahani O, Pietsch M. The painful knee after TKA: a diagnostic algorithm for failure analysis. Knee Surg Sports Traumatol Arthrosc. 2011 Sep;19(9):1442-52. doi: 10.1007/s00167-011-1634-6. Epub 2011 Aug 6. PMID: 21822665.

36. Zaghlol, R.S., Khalil, S.S., Attia, A.M. *et al.* Comparison of two different models of rehabilitation programs following total knee replacement operations. *Egypt Rheumatol Rehabil* **47**, 31 (2020). https://doi.org/10.1186/s43166-020-00034-1