Original Article

Effects of balance exercises on foot pressure distribution after total knee arthroplasty

Hossein Afzali[1], Fateme Ghiasi[2*], Mohammad Hosseinifar[2], Hassan Namvar[2], Ahmadreza Asgariashtiani[2]

[1]Msc.Student, Department of Physiotherapy, School of Rehabilitation, Zahedan University of Medical Sciences, Zahedan, Iran. [2]Assistant Professor, Rehabilitations Sciences Research Center, Zahedan University of Medical Sciences, Zahedan, Iran.

Correspondence: **Fateme Ghiasi**, Assistant Professor, Rehabilitations Sciences Research Center, Zahedan University of Medical Sciences, Zahedan, Iran. F_ghiasi_p@yahoo.com, fqiasi@gmail.com.

ABSTRACT

Improper distribution of foot pressure and abnormal balance on the foot in patients with total knee arthroplasty (TKA) can lead to early mechanical failure in surgery and the prosthesis. Therefore, this study aimed to investigate the effect of balance exercises on foot pressure distribution after TKA. In this randomized clinical trial, 30 subjects with total knee arthroplasty were included. The subjects were randomly divided into a routine exercise group and a balance exercise group.

The rehabilitation program was conducted for 30 minutes, 6 days a week, and for 12 sessions. Patients were evaluated before and after surgery, as well as after the intervention, were evaluated in terms of foot plantar pressure, forefoot pressure, rearfoot pressure, surface in contact with the ground in the foot, ellipse area, and center of pressure (COP) path length using a foot pressure scanning machine. Pain intensity in patients was measured using a visual analog scale (VAS). Data were analyzed using multiple ANOVA repeated measures and the Bonferroni test ($P<0.05$). The results showed that there is a significant difference in the foot plantar pressure distribution before and after balance exercises ($p<0.05$). The shift of the sole pressure from the forefoot to the rear foot was significant in the group of balance exercises ($p<0.05$). Also, balance exercises are more effective in reducing pain intensity compared to routine exercises ($P<0.0001$). The amount of pressure distribution after the intervention in both legs is not significant in the balance exercise group ($p>0.05$) The results show that balance exercises are effective in improving plantar pressure distribution and balance in patients with total knee arthroplasty. Additionally, balance exercises have a positive effect on achieving a proper pressure distribution on both legs. Therefore, it is recommended that in addition to routine exercises, balance exercises should also be considered in subjects with total knee arthroplasty.

Keywords: Total Knee Arthroplasty, Balance Exercises, Foot Pressure Distribution

Introduction

Total knee arthroplasty (TKA) is one of the most common surgeries performed and its number has been gradually increasing in recent years (1, 2). It is well known that total knee replacement surgery reduces pain and improves the function of a patient, but its effect on foot pressure distribution and postural reaction. On the other hand, changing the function of the knee joint can change the balance and the amount of pressure on the sole (3).

After TKA, changes in the loading pattern can affect the surgical outcome (4). Knee prosthesis instability is one of a common cause of TKA failure (5). Additionally, TKA results in the loss of a major portion of knee joint proprioception provided by the receptors on the joint surface, with only a remaining portion provided by the tendons, capsules, and ligaments surrounding the knee. This decrease in sensory and joint receptors disrupts balance and proprioception in patients, leading to altered pressure patterns on the feet (6). People with knee osteoarthritis after TKA usually have impaired proprioception (7, 8), altered muscle activation patterns (9, 10), and weakness (especially in the quadriceps) (11-14). This condition causes non-physiological loading of the knee joint and progressive degeneration of the knee joint (15, 16). Therefore, foot pressure distribution and postural reaction would be changed after TKA. The foot soles, despite their small surface area, play a crucial role in maintaining body balance (17). There is concern among many knee

arthroplasty surgeons that abnormal foot pressure or abnormal loading can apply abnormal forces to the knee prosthesis, which can lead to early mechanical failure (4). Improper distribution of pressure and loadings with deviations from the normal alignment led to a risk of injury, falling, and failure of surgery in people with TKA (18). As a result, balance exercises can be effective in improving postural stability and normal foot pressure distribution after TKA (3, 19, 20). Arik et al. (2018) evaluated distribution patterns of pressure on the foot changed after TKA. Load on the forefoot during standing increased significantly after TKA, while the load on the rearfoot decreased significantly. Normal foot pressure distribution was improved 15 days after TKA (21). Lee et al. (2021) showed the effect of dynamic stability training on physical performance, ability to maintain balance, and quality of life in TKA patients (22). Thonga et al. (2021) also found the positive effects of a close-kinetic-chain exercise on function, and balance reaction in patients with TKA (19). Safaribak et al. (2016) showed that eight weeks of selected balance exercises can significantly improve balance indexes, including overall balance, anterior-posterior balance, and internal-external balance, in elderly people with knee osteoarthritis. It is possible to suggest these exercises could improve balance reaction and prevent falling in elderly individuals with knee osteoarthritis (23). Based on this information, the purpose of this clinical trial was to evaluate the effect of balance exercises on foot pressure distribution after TKA.

Materials and Methods

This study was a simple randomized controlled trial. Thirty patients with TKA voluntarily participated in this study. The patients were divided into two groups using a simple non-probability sampling method. The medical ethics committee at Zahedan University of Medical Sciences (ZUMS) approved the study ethics and issued the ethics certification number IR.ZAUMS.REC.1402.195. It was also registered with the region's Clinical Trials Registry IRCT20180714040466N6. All participants signed a written informed consent form before starting the trial.

Inclusion Criteria

The inclusion criteria included a maximum time of 1 month after TKA, unilateral arthroplasty, no physical therapy intervention/rehabilitation after hospital discharge for TKA, age less than 80 years, and no history of knee surgery within 6 months before the study.

Exclusion Criteria

Patients who do not want to participate in the study or are unable to tolerate balance exercises will be excluded from the study.

Sample Size

The sample size was determined based on a pilot study. Ten patients who met the inclusion criteria were randomly divided into two equal groups, and the main part of the study was conducted on them. The means and standard deviations (SDs) for the parameters from this pilot study, with $\alpha = 0.05$ and 90% power, were used to calculate the sample size.

$n = (Z_{1-\alpha/2} + Z_{1-\beta})^2 (S_1^2+S_2^2) / (\mu_1-\mu_2)^2$

$Z_{1-\alpha/2} = 1.96$

$Z_{1-\beta} = 1.28$

According to the results of the pilot study and the stated formula, the sample size in each group was 17 patients.

The sampling method used was a simple, non-probabilistic sampling method and from the available population. The participants will then be randomly allocated to two intervention groups: one group receiving routine physiotherapy and the other group receiving balance exercise and routine physiotherapy. Randomization will be performed using a random number sequence. The patients were not informed about the details of the study. The administrator and participants were informed about the grouping data. However, the physiotherapist who evaluated the patients measured the outcomes and analyzed the data was blinded to the groups.

Procedure

Patients who were referred to a personal physiotherapy clinic were selected based on the inclusion and exclusion criteria. First, the demographic and pain information of the patients was completed to evaluate the subjective symptoms. Foot pressure parameters were evaluated before surgery, and before and after the intervention. The baropodometric data collection tool used was a foot pressure scanner (Payatech model, PT-Scan4452F100). Then, the patients were randomly assigned to two treatment groups: routine physiotherapy (TENS, hot pack, exercises with emphasis on quadriceps muscle strengthening) and balance exercises (TENS, hot pack, balance exercises).

Outcomes

The initial assessment of patients was conducted before surgery. Then, the patients underwent subjected to routine exercises and balance exercises, which lasted for a maximum of one month after the surgery. After the completion of the treatment period, the patients were evaluated once again.

Pain intensity

The VAS (Visual Analogue Scale) of the McGill Short Questionnaire was used to evaluate the intensity of pain. The VAS is a 100-mm, non-graded horizontal line with fixed boundaries from no pain to worst possible pain, on which the patient marks their pain severity.

Measurement of foot pressure

Foot plantar pressure percentage and center-of-pressure parameters were recorded in patients of two groups before surgery and after intervention. The evaluation was done using a scanner device in three repetitions, and the average measurements were reported. The interval between assessments was 5 minutes.

In this test, the person stood on the device without shoes and without moving (static), and the pressure caused by the soles of the feet was recorded. The evaluated parameters in the operated and healthy foot included the percentage of foot plantar pressure, forefoot pressure, rearfoot pressure, and the surface in contact with the ground on the foot (cm^2).

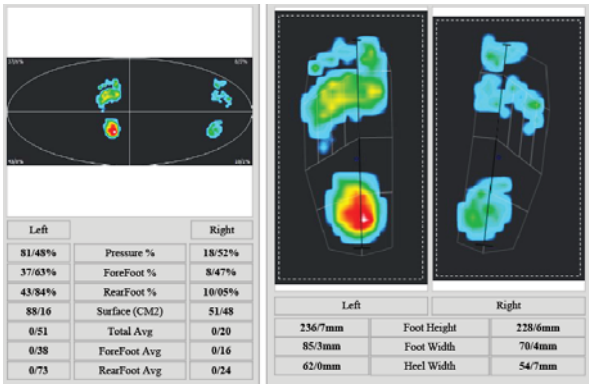

Figure 1. Measuring the percentage of foot pressure in a 60-year-old female patient

Center of Pressure Balance Test

The parameters measured in this test allow for checking the patient's physical condition during the treatment. In this test, the patient stood on the device for 10 seconds normally without speaking, and it was ensured that the patient did not move excessively during the test. During this test, the movement path of the body's center of pressure was recorded. Based on this, the Ellipse Area (mm^2) that encloses the path of COP movement and the COP path length, which is obtained by connecting the points of the center of pressure at any moment (mm), were determined. The reduction of the oval area and COP path length during the treatment period indicates an improvement in the disease.

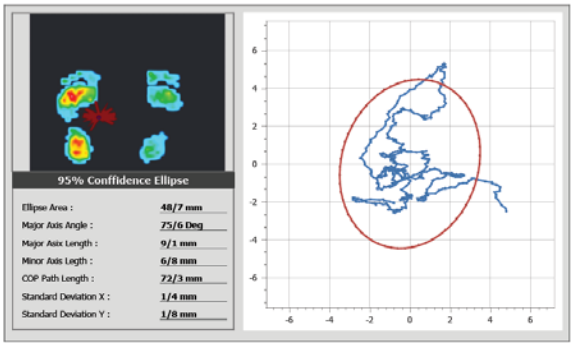

Figure 2. Center of pressure balance test measurements

Intervention

Patients were randomly divided into two groups: the balance exercises group and the routine treatment group. In the routine treatment group, patients received only routine physiotherapy treatment. In the balance exercises group, patients received balance exercises in addition to routine treatment.

In the patients of the balance exercises group, the subjects were trained with a balance exercise rehabilitation program for 30 minutes, 6 days a week, and for 12 sessions. Balance exercises included standing on one leg with eyes open and closed, and anterior, lateral, and posterior step-up exercises in both legs of the patient (24, 25). In the control group, the patients received TENS (Transcutaneous Electrical Nerve Stimulation) electrotherapy for 20 minutes and Infrared Radiation (IR) for 10 minutes. Subsequently, stretching exercises for the hamstring muscles and strengthening exercises for the quadriceps muscles were conducted for 30 minutes.

The patients were treated in 12 sessions six days a week for two weeks. All the variables were measured before surgery, before intervention, and after intervention.

Data Analysis

The results were presented as mean values and standard deviations (SD). The criterion of significance was set as $p<0.05$. Data analysis was performed with SPSS version 27. The assumption of a normal distribution was assessed using the Shapiro-Wilk test. The statistical tests did not reject the hypothesis of normality and the data were normal ($p>0.05$). The assumption of equality of variances was evaluated using Levene's test. The Mixed model repeated measure ANOVA and Bonferroni correction were used for within- and between-group comparisons. The p-value was considered to be less than 0.05

Results and Discussion

Forty people were nominated for this study, and 34 of these patients were divided into two groups: the balance exercises group and the routine group (Figure 4). The pilot study showed that 17 subjects would be needed for each group (a total of 34 subjects). Ultimately, 30 subjects finished the study procedure. Two subjects from the balance exercises group and two subjects from the routine group left the study because of personal problems, unwillingness to continue treatment, incomplete treatment, or reasons unrelated to the investigation. The flowchart of choosing participants in the study is shown in Figure 4.

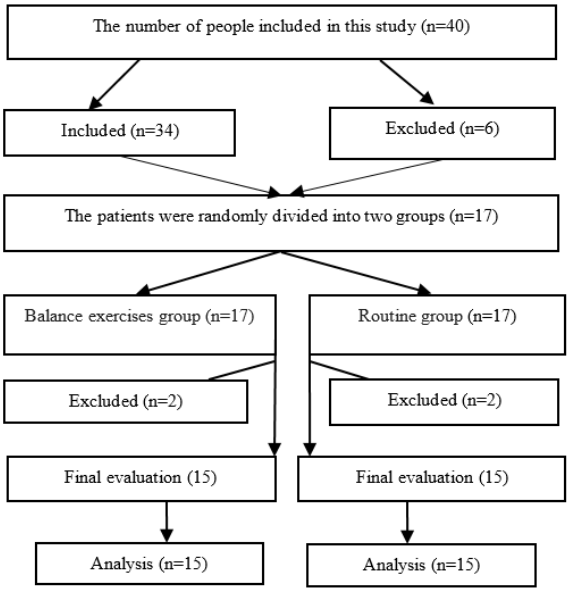

Figure 4. Flow diagram of study selection.

Table 1 presents the demographic characteristics of patients, including age, height, weight, and body mass index. The demographic characteristics of the patients, which were recorded before the intervention, were compared between the two study groups. There was no significant difference between the two groups (Table 1).

Table 1. Comparison of demographic characteristics between two groups.

Variable	Routine group*	stability exercises group*	Sig**
Age (Years)	47.05±8.6	44.50±8.5	0.34
Weight (Kg)	77.27±13.1	74.05±11.2	0.40
Height (Cm)	169.64±6.2	167.50±5.9	0.26
Body Mass Index (BMI) (Kg/m2)	26.66±3.0	26.25±2.7	0.64

*mean ± standard deviation. ** A significance level of less than 0.05.

To examine the homogeneous of the samples in two groups before intervention, a t-test was used. The results showed that the samples in two groups were equal and homogeneous (p>0.05).

Within group and between group comparison

Table 2. Within and between group comparison of the variables before and after surgery and after the intervention in two groups

Variable	Routine physiotherapy group*			stability exercises group*			Within Sig**	between Sig **
	before surgery	after surgery	after intervention	before surgery	after surgery	after intervention		
foot plantar pressure	29.21±6.49	45.86±14.66	48.28±9.32	38.06±12.98	45.74±17.08	50.12±4.04	0.001	0.94
forefoot pressure	19.56±4.22	26.41±15.83	24.58±6.21	22.82±4.45	26.12±9.21	20.75±7.03	0.09	0.87
rearfoot pressure	19.59±4.18	30.93±21.17	24.58±6.76	18.20±10	28.03±13.37	25.55±4.37	0.007	0.67
surface	89.88±10.52	96.29±56.32	91.83±28.88	87.24±20.56	100.01±31.38	116.37±55.28	0.15	0.40
ellipse area	127.63±102.19	110.19±100.31	139.30±162.40	127.54±102.90	161.65±118.18	89.02±92.74	0.64	0.99
COP path length	95.43±23.23	97.85±23.36	93.69±19.49	96.47±39.12	112.24±46.82	88.47±22.29	0.10	0.67
pain intensity	9.13±0.99	5.87±0.92	2.67±0.98	8.66±1.11	4.6±1.24	1.20±1.01	0.000	0.000

*mean ± standard deviation. ** A significance level of less than 0.05.

The results of Table 2 showed that the changes in foot plantar pressure, rearfoot pressure, forefoot pressure, and pain intensity were significant before and after surgery and after intervention in both groups (p<0.05). The results of the between-group comparison showed that there was no significant difference between the two groups in all states (p>0.05).

The results of the Bonferroni test in Table 2 indicated a significant difference between the foot plantar pressure and forefoot pressure before surgery and after the intervention (p<0.05) in both groups. However, there was no significant difference in foot plantar pressure (p>0.05), while there was a significant difference between forefoot pressure (p=0.014) before and after surgery.

The Bonferroni test results showed that there was no significant difference in rearfoot pressure in the two groups before and after surgery (p>0.05). Also, no significant difference was observed after intervention (p>0.05).

The Bonferroni test results showed a significant difference in the pain intensity before and after surgery (p<0.05). The pain intensity after intervention (p<0.0001) was also significantly reduced compared to before surgery (table 2).

Healthy foot and operated foot comparison in groups

Table 3. Comparison between two legs (healthy foot and operated foot) in two groups

Variable	Time	Routine physiotherapy group*			stability exercises group*		
		operated foot	healthy foot	Sig**	operated foot	healthy foot	Sig **

foot plantar pressure	before surgery	39.22±6.49	60.78±6.49	0.000	38.06±12.98	61.78±13.11	0.003
	after surgery	45.86±14.57	51.33±14.56	0.42	45.74±17.08	45.86±20.87	0.99
	after intervention	48.28±9.32	51.72±9.31	0.48	50.12±4.04	46.88±12.27	0.39
forefoot pressure	before surgery	19.56±4.22	28.08±4.39	0.000	22.52±4.45	29.04±8.29	0.009
	after surgery	26.41±15.83	32.33±23.67	0.12	26.12±9.21	23.47±11.57	0.59
	after intervention	24.58±6.20	25.66±5.90	0.67	20.75±7.03	24.56±4.68	0.056
rearfoot pressure	before surgery	19.60±4.18	32.70±6.04	0.000	18.20±10	32.83±7.53	0.003
	after surgery	30.93±21.17	31.06±17.62	0.97	28.03±13.38	23.38±11.12	0.35
	after intervention	24.57±6.76	26.05±6.11	0.59	25.55±4.37	25.38±5.25	0.88
surface	before surgery	89.89±10.52	102.84±30.80	0.006	87.20±20.56	99.63±19.97	0.02
	after surgery	96.29±56.32	90.84±30.80	0.74	100±31.37	88.01±35.82	0.21
	after intervention	91.83±25.87	100.34±20.39	0.35	116.37±55.28	117.21±54.37	0.69

*mean ± standard deviation. ** A significance level of less than 0.05.

The results of Table 3 showed that there was a significant difference in foot plantar pressure, forefoot pressure, rearfoot pressure, and surface before surgery ($p<0.01$) and were higher in the healthy foot. The results of the between-foot comparison showed that there was no significant difference between these variables after surgery and intervention in the two groups ($p>0.05$).

The most important finding of the research showed that balance exercises are effective in correcting the pressure distribution of the soles of the feet and establishing balance. This research showed that the distribution of pressure between the forefoot and rear foot as well as both legs is well-adjusted and uniform.

The distribution of the maximum pressure on the sole of the foot can indicate the loads on the areas above the foot, such as the knee, and helps identify complications after treatment in patients (26). Considering that the lower limb is an integrated kinetic chain, any inappropriate loading on the sole of the foot leads to the development of side effects in other parts of this chain. Therefore, any deviation, abnormality, or biomechanical changes in any part of the foot directly affect the loads applied to the knee (27).

Post-TKA balance exercises, especially those that emphasize training the sensory systems of balance, challenge the sensory systems for balance and thus improve balance outcomes (e.g., walking capacity, one-leg standing time) (28). Exercises specifically designed to induce leg instability and/or visual impairment compensate for knee proprioception by increasing the ankles and hip proprioception (29), stimulating neuromuscular feedback control, and thus improving the patient's balance and postural stability (30). In closed chain exercises, which is the distal part of the fixed body, multi-joint work is done and a group of muscles are active. By co-contraction the muscles around the knee joint, the stability of the knee joint is increased. So, while maintaining the stability of the knee joint, it also increases muscle strength. This result corresponds to the goals of rehabilitation of patients with knee arthroplasty. The goals of rehabilitation in these patients are to increase mobility, education transfer, and improve walking and climbing stairs. It is obvious that without a functional exercise program, goals such as learning to walk and climbing stairs cannot be achieved (148According to the results of the current study, it was found that performing balance and closed chain exercises can adjust the pressure on the soles of the feet. According to the results of the current study, it was found that performing balance and closed chain exercises can adjust the pressure on the soles of the feet. Our study supports the findings of Abbas and Daher (2017), An et al. (2023), and Hui et al. (2022), who also emphasize the importance of implementing a closed chain program for patients after knee arthroplasty. These researchers believe that closed chain exercises can enhance muscle strength, promote joint stability, increase physical activity and patient performance, and ultimately improve balance and create symmetry in the body. (148,149,150). In this study, the exercises used for patients in the balance exercises group placed the patient in unstable conditions (such as standing on one leg) or induced instability in the legs (such as anterior, lateral, and posterior step-up). When exposed to unstable conditions and equipment that induces instability in the legs, all vision, proprioceptive, and vestibular systems are activated, which are essential for optimizing balance capabilities (31). Similar to the results of the present study, the effectiveness of stability exercises and physiotherapy exercises in distributing pressure and improving balance in patients has been demonstrated. Piva et al., (2010) showed that patients with TKA experienced improvements in walking speed and standing time on one leg (32). Rajhani Shirazi et al. (2013) also investigated the effect of stability exercises on joint proprioception and balance time. They found that stability exercises improved the balance time on one leg and proprioception in the knee and ankle joints (33). Arik et al. (2018) reported that load distribution on the soles of the feet in a static position improved 15 days after surgery in TKA patients (21). In a meta-analysis study, the effectiveness of balance training on walking capacity and balance performance in elderly people after TKA was shown (28). Another systematic review in 2016 reported that various factors such as proprioceptive improvement, normal reaction postural control, and joint and muscle coordination lead to improvement in patients' balance (34). Improving the somatosensory sensation of the soles of the feet in these exercises will help improve balance in these people (35). As a result, this study showed that the use of closed chain and balance exercises at the beginning of the rehabilitation program can be recommended and have beneficial effects in improving the foot pressure distribution and balance in patients with TKA.

Conclusion

In the current study, no difference was observed between the two groups of balance and routine exercises. However, it did demonstrate the role of balance exercises in creating symmetry in the body and balancing the pressure on the soles of the feet. Therefore, we suggest that in addition to routine exercises, balance exercises should also be considered in subjects with TKA.

Authors' Contributions:

All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

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Conflict of interest: None

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Ethics statement: None

References

1. Fuchs J, Kuhnert R, Scheidt-Nave C. 12-Monats-Prävalenz von Arthrose in Deutschland. 2017.
2. Heidari B. Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I. Caspian journal of internal medicine. 2011;2(2):205.
3. Notarnicola A, Maccagnano G, Fiore A, Spinarelli A, Montenegro L, Paoloni M, et al. Baropodometry on patients after total knee arthroplasty. Musculoskeletal Surgery. 2018;102:129-37.
4. Voronov ML, Pinzur MS, Havey RM, Carandang G, Gil JA, Hopkinson WJ. The relationship between knee arthroplasty and foot loading. Foot & Ankle Specialist. 2012;5(1):17-22.
5. Rodriguez-Merchan EC. Instability following total knee arthroplasty. HSS Journal®. 2011;7(3):273-8.
6. Bragonzoni L, Rovini E, Barone G, Cavallo F, Zaffagnini S, Benedetti MG. How proprioception changes before and after total knee arthroplasty: a systematic review. Gait & Posture. 2019;72:1-11.
7. Hassan BS, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Annals of the rheumatic diseases. 2001;60(6):612-8.
8. Hurley MV, Scott DL, Rees J, Newham DJ. Sensorimotor changes and functional performance in patients with knee osteoarthritis. Annals of the rheumatic diseases. 1997;56(11):641-8.
9. Hinman RS, Bennell KL, Metcalf BR, Crossley KM. Delayed onset of quadriceps activity and altered knee joint kinematics during stair stepping in individuals with knee osteoarthritis. Archives of physical medicine and rehabilitation. 2002;83(8):1080-6.
10. Hortobágyi T, Garry J, Holbert D, Devita P. Aberrations in the control of quadriceps muscle force in patients with knee osteoarthritis. Arthritis Care & Research. 2004;51(4):562-9.
11. Hall MC, Mockett SP, Doherty M. Relative impact of radiographic osteoarthritis and pain on quadriceps strength, proprioception, static postural sway and lower limb function. Annals of the rheumatic diseases. 2005.
12. Jan M-H, Lai J-S, Tsauo J-Y, Lien I-N. Isokinetic study of muscle strength in osteoarthritic knees of females. Journal of the Formosan Medical Association= Taiwan yi zhi. 1990;89(10):873-9.
13. Messier SP, Loeser RF, Hoover JL, Semble EL, Wise CM. Osteoarthritis of the knee: effects on gait, strength, and flexibility. Archives of physical medicine and rehabilitation. 1992;73(1):29-36.
14. Slemenda C, Brandt KD, Heilman DK, Mazzuca S, Braunstein EM, Katz BP, et al. Quadriceps weakness and osteoarthritis of the knee. Annals of internal medicine. 1997;127(2):97-104.
15. Hopman-Rock M, Odding E, Hofman A, Kraaimaat FW, Bijlsma JW. Differences in health status of older adults with pain in the hip or knee only and with additional mobility restricting conditions. 1997.
16. Jadelis K, Miller ME, Ettinger Jr WH, Messier SP. Strength, balance, and the modifying effects of obesity and knee pain: results from the Observational Arthritis Study in Seniors (OASIS). Journal of the American Geriatrics Society. 2001;49(7):884-91.
17. Hertel J, Gay MR, Denegar CR. Differences in postural control during single-leg stance among healthy individuals with different foot types. Journal of athletic training. 2002;37(2):129.
18. HamedEsmaeili, Ghasemi M, Anbarian M, Ghavimi A. Comparison of plantar pressure distribution in runners with different foot structures. IJRN 2018;5(1):8-18. farsi.
19. Thonga T, Stasi S, Papathanasiou G, Thonga TC. The effect of intensive close-kinetic-chain exercises on functionality and balance confidence after total knee arthroplasty. Cureus. 2021;13(10).
20. Woźniak-Czekierda W, Woźniak K, Hadamus A, Białoszewski D. Use of kinesiology taping in rehabilitation after knee arthroplasty: a randomised clinical study. Ortopedia Traumatologia Rehabilitacja. 2017;19(5):461-8.
21. Arık MI, Aras Ö, Akkan H, Şahin NY, Kurt V, Aksoy CC, et al. How does Plantar Pressure Distribution Change Early after Total Knee Arthroplasty? A Pilot Study. Osmangazi Tıp Dergisi. 2018.

22. Lee H-G, An J, Lee B-H. The effect of progressive dynamic balance training on physical function, the ability to balance and quality of life among elderly women who underwent a total knee arthroplasty: a double-blind randomized control trial. International journal of environmental research and public health. 2021;18(5):2513.

23. Safaribak M, koshraftaryazdi N, Aghajani A. The Effect of Eight Weeks Exercises on Balance Indexes in Elderly Patients with Knee Osteoarthritis Mashhad paramedical and rehabilitation sciences. 2017;2(6):86-97. farsi.

24. Akbari A, Ghiasi F, Mir M, Hosseinifar M. The effects of balance training on static and dynamic postural stability indices after acute ACL reconstruction. Global journal of health science. 2016;8(4):68.

25. Risberg MA, Lewek M, Snyder-Mackler L. A systematic review of evidence for anterior cruciate ligament rehabilitation: how much and what type? Physical Therapy in Sport. 2004;5(3):125-45.

26. Kour N, Gupta S, Arora S. A survey of knee osteoarthritis assessment based on gait. Archives of Computational Methods in Engineering. 2021;28:345-85.

27. Lidtke RH, Muehleman C, Kwasny M, Block JA. Foot center of pressure and medial knee osteoarthritis. Journal of the American Podiatric Medical Association. 2010;100(3):178-84.

28. Doma K, Grant A, Morris J. The effects of balance training on balance performance and functional outcome measures following total knee arthroplasty: a systematic review and meta-analysis. Sports Medicine. 2018;48:2367-85.

29. Bunton EE, Pitney WA, Cappaert TA, Kane AW. The role of limb torque, muscle action and proprioception during closed kinetic chain rehabilitation of the lower extremity. Journal of athletic training. 1993;28(1):10.

30. Liao C-D, Liou T-H, Huang Y-Y, Huang Y-C. Effects of balance training on functional outcome after total knee replacement in patients with knee osteoarthritis: a randomized controlled trial. Clinical rehabilitation. 2013;27(8):697-709.

31. Kuo AD. An optimal state estimation model of sensory integration in human postural balance. Journal of neural engineering. 2005;2(3):S235.

32. Piva SR, Gil AB, Almeida GJ, DiGioia III AM, Levison TJ, Fitzgerald GK. A balance exercise program appears to improve function for patients with total knee arthroplasty: a randomized clinical trial. Physical therapy. 2010;90(6):880-94.

33. RajhaniShirazi Z, Shafaei R, Afrandihe M. Survey on the Effects of Balance Training on Proprioception of Knee and Ankle Joints and Equilibrium Time in Single Leg in Healthy Female Students. JRUMS 2011;10(4):289-98. Farsi.

34. Moutzouri M, Gleeson N, Billis E, Panoutsopoulou I, Gliatis J. What is the effect of sensori-motor training on functional outcome and balance performance of patients' undergoing TKR? A systematic review. Physiotherapy. 2016;102(2):136-44.

35. Park JH, Benson RF, Morgan KD, Matharu R, Block HJ. Balance effects of tactile stimulation at the foot. Human Movement Science. 2023;87:103024.