DIFFERENCES IN EFFECTIVENESS BETWEEN SQUARE STEPPING EXERCISE AND OTAGO EXERCISE ON INCREASING MUSCLE STRENGTH, STEP LENGTH, AND DYNAMIC BALANCE IN KNEE OSTEOARTHRITIS SUFFERERS

Rosmin[1,2], Djohan Aras [3], Andi Ariyandy [3], Irfan Idris 4, Meutiah Mutmainnah Abdullah[4], Nukhrawi Nawir[4]

Abstract

This study aims to determine the difference in effectiveness between the square stepping exercise and the Otago exercise on increasing muscle strength, stride length, and dynamic balance in patients with knee osteoarthritis. This research is a quasi-experimental study with a pretest-posttest design with 2 paired groups. A total of 36 people suffering from knee osteoarthritis were divided into two groups, each consisting of 18 people. The first treatment group was given a square stepping exercise and the second treatment group was given an Otago exercise. Paired t-test was used to determine changes before and after giving training and an independent t-test to determine comparisons between treatment groups. Before being given treatment in the first week, pretest leg muscle strength using the 30-second chair stand test (30 SCT), stride length using meterline and balance measurement using time up and go (TUG). then in the eighth week, a posttest was carried out after 15 treatments. There was an increase in muscle strength, stride length, and dynamic balance in the treatment group that was given the square stepping exercise and the treatment group that was given the Otago exercise (p=0.000). Furthermore, the independent t-test found that the square stepping exercise has a higher difference in increasing muscle strength and decreasing dynamic balance than the Otago exercise (p = 0.492 and p = 0.000), but with increasing stride length, a higher difference in step length addition is obtained. on Otago exercise than square stepping exercise (p=0.263). This study shows that 5 weeks of square stepping exercise is more effective in increasing dynamic balance compared to Otago exercise.

Keywords: Osteoarthritis knee, square stepping exercise, Otago exercise, 30 SCT, meterline, TUG

[1)] Dapertement Of Physiology, Faculty Of Medicine Hasanuddin University, Makassar, Indonesia
[2)] Dapertement Of Physiology, Nursing Faculty Hasanuddin University, Makassar, Indonesia
[3)] Dapertement Of Physiology, Faculty Of Medicine Hasanuddin University, Makassar, Indonesia
[4)] Dapertement Of Physiology, Nursing Faculty Hasanuddin University, Makassar, Indonesia
[5)] Dapertement Of Physiology, Faculty Of Medicine Hasanuddin University, Makassar, Indonesia
Correspondent: aderos850@gmail.com

1. Introduction

Osteoarthritis of the knee is an arthritic condition of the knee joint which is characterized by progressive damage to the cartilage and tissue around the joint (Cueva et al., 2022). Osteoarthritis of the knee is a chronic degenerative disease involving inflammation and structural changes in the joints, resulting in joint pain and physical functional limitations (Pereira et al. 2022).

Knee osteoarthritis is often experienced by the elderly with symptoms such as chronic pain, crepitus, edema, morning stiffness, atrophy, decreased muscle strength, decreased stride length, and disturbed dynamic balance in carrying out functional activities which will ultimately reduce the sufferer's physical capacity (Kalo et al., 2022). Difficulty in controlling posture by people with osteoarthritis can cause a lack of instability due to an imbalance in the body's center of gravity. Affects body coordination in maintaining postural control, causing balance disorders due to muscle imbalance around the joints. Causing disturbances in gait patterns, thereby reducing stride length which can increase the risk of falling in patients with knee osteoarthritis (Chen et al. 2021).

Some exercises that are effective in reducing symptoms and functional decline in patients with knee osteoarthritis include aerobic, resistance, balance exercises such as square-stepping exercises and Otago exercises where these exercises involve the strength of the muscles of the lower limbs. This exercise program consists of several components which can be increased stride length followed by flexibility exercises and coordination exercises. To improve the dynamic postural balance, proper handling is needed to maintain the body centered in equilibrium when moving (Abdullah and Nur'amalia 2022).

Square stepping exercises can improve dynamic control related to gait and locomotion. This exercise stimulates dynamic balance through the proprioceptive system in the joints and the visual sensory system in maintaining balance. These changes can improve the musculoskeletal system thereby increasing stride length to improve walking patterns (Murtiani and Suidah 2019). Otago exercise is one of the repetitive proprioception exercises that can improve proprioception and muscle strength which has an important role in the rehabilitation of elderly individuals (Joshi and Phansopkar 2022). So that researchers are interested in researching the difference in effectiveness between square stepping exercise and Otago exercise on increasing muscle strength, stride length, and dynamic balance in patients with knee osteoarthritis.

2. Materials and Methods

The study subjects were 36 people with knee osteoarthritis at Hati Mulia general hospital who met the inclusion criteria and did not include the exclusion criteria. Inclusion criteria in this study were patients who were willing to become respondents, aged ≥60 years, chronic knee (Symptoms > 1 month), had no history of post fracture of the tibial condyle or femur and deformity, tumor, edema, and knee joint effusion and diagnosed with knee osteoarthritis. From an expert doctor. Exclusion criteria in this study were patients who were uncooperative and had body mass index (BMI) in the overweight category. This research was approved by the Ethics Committee for Health Research, Faculty of Public Health, Hasanuddin University, Makassar, Indonesia with an ethical license number 2557/UN4.14.1/TP.01.02/2023.

Subjects were divided into 2 groups, each group consisting of 18 people. The first group was the intervention group by giving square stepping exercises and the second treatment group was the intervention group by giving Otago exercise. Each was given exercise 3 times a week for 5 weeks.

The square stepping exercise is an exercise using a thin mat (100 cm × 250 cm) divided into 40 squares of 25 cm each with 3 levels of walking pattern. The first level (beginner), namely, the level by walking straight ahead using two rows of boxes in the middle of the mat stepping up to the end of the box. The second level (intermediate) is the pattern of movement that starts in the two row boxes in the middle then walks forward plus the right and left sides then returns to the middle row until the end of the box. The

third level, the zig-zag walking pattern, a movement pattern that starts in the two row boxes in the middle to the end of the contact.

Otago exercise is a multi-component exercise that focuses on flexibility, strength, balance, and endurance and can effectively improve balance, mobility, and physical performance. Each practice session involves knee bends backward walking, walking and turning around, sideways walking, and heel walking-no support. Before starting the exercise treatment for the respondents, first, in the first week, a pre-test was carried out to assess muscle strength, stride length, and dynamic balance. Then, in the fifth week, a post-test was carried out after 15 treatments. Examination of muscle strength using a 30-second chair stand test in which participants were instructed to repeatedly stand up from a chair and sit back with their arms crossed over their shoulders, at the same time counting how many times the participant stood for thirty seconds was counted. Calculation of stride length was carried out using a meterline, in which participants were instructed to walk as usual with feet that had been inked and then measured step length on the same foot prints and measurements of balance using the time up and go test (TUGT), in which participants were instructed to walk 3 meters according to the line on the floor at normal speed then turn around and sit back, when you start walking, the time calculation begins and the time ends after the participant sits back on the chair.

Statistical analysis was performed with SPSS program version 26.0 (IBM Corporation, Armonk, NY, USA). Numerical data are presented as mean and standard deviation, categorical data are presented as frequencies and percentages. The collected data will be tested for normality using the Shapiro Wilk test, otherwise the data is normally distributed if $p > 0.05$. Paired t-test was used to see the effect before and after administration of the square stepping exercise and Otago exercise on changes in muscle strength, stride length, and dynamic balance in patients with knee osteoarthritis. An independent t-test was used to compare differences in stepping exercise and Otago exercise on changes in muscle strength, stride length, and dynamic balance after a five-week exercise program between the two groups. The significance level was set at $p < 0.05$.

3. Results and Discussion

Respondent characteristics are shown in Table 1 with frequency distribution data including age, gender, and duration of suffering by giving square stepping exercise and Otago exercise to changes in muscle strength, stride length, and dynamic balance in the two treatment groups.

Tabel 1. Respondent characteristics

Characteristics	***Square stepping exercise***		***Otago exercise***		***Total***
	Amount	***Percent (%)***	***Amount***	***Percent (%)***	
Age (years)					
60-63	*4*	*22.2*	*3*	*16.7*	*7*
64-67	*9*	*50.0*	*10*	*55.6*	*19*
68-70	*5*	*27.8*	*5*	*27.8*	*10*
Total	*18*	*100*	*18*	*100*	*36*
Gender					
Male	*2*	*11.1*	*7*	*38.9*	*9*
Female	*16*	*88.9*	*11*	*61.1*	*27*
Total	*18*	*100*	*18*	*100*	*36*
Long suffered OA knee					
>3	*14*	*11.1*	*12*	*66.7*	*17*
<3	*4*	*88.*	*6*	*33.3*	*9*
Total	*18*	*100*	*18*	*100*	*36*

Based on age category, it was obtained in the intervention group that was given square stepping exercise in the most age category, namely at 64-67 years as much as 9 or 50%, while in the group given Otago exercise, namely at 64-67 years, as many as 10 or 56%. Based on the global prevalence of knee osteoarthritis, there are 22.9% of people aged 40 years and over, and in 2020, there are around 654 million people aged 40 years and over with knee osteoarthritis (Hinman et al. 2022). According to the World Health Organization (WHO), by 2050, around 20% of the world's population aged over 60 years of 15% will have symptoms of osteoarthritis, and one-third will experience severe paralysis (Cueva et al., 2022).

As people get older, difficulties in controlling posture by people with osteoarthritis can cause a lack of instability due to an imbalance in the body's center of gravity. Balance affects body coordination in maintaining postural control. Balance affects body coordination in maintaining postural control. Disorders of balance can result in an imbalance in the muscles around the joints. Disturbing gait patterns, thus reducing stride length due to lower leg muscle weakness which can increase the risk of falling in patients with knee osteoarthritis (Chen et al. 2021). Where at the age of 60, only 85% of the elderly walked in a normal pattern, but at the age of 85, only 18% of the elderly walked in a normal pattern (Munawwarah and Halimah 2020).

In the gender category, it is known that women are the majority sample in the first treatment group at 89% and the second treatment group at 61%. This happens because, at the age of 62 years, women experience a decrease in estrogen production which can cause osteoarthritis due to a decrease in collagen matrix so that cartilage becomes damaged and causes pain. Muscle development in men and women experience differences where the size of the muscles in men is greater than in women. This is related to the level of the male hormone testosterone which increases after puberty. Large muscle size will increase muscle strength and in men, muscle strength reaches its peak at the age of 20 (Setiorini 2021).

Although the metabolic mechanisms in women with osteoarthritis of the knee, associated with obesity, make adipose tissue release cytokines and adipocytokines which can disrupt cartilage homeostasis thereby slowing joint repair (Joshi, Singh, and Vij 2018).

As well as the long-standing factor of suffering from knee osteoarthritis, it was found in the first treatment group at most < 3 years, namely 88% and in the second treatment group, the most also at < 3 years, namely 67%. The duration of suffering from osteoarthritis of the knee makes the postural muscles weaken and reduces the muscle response to become less synergistic, this will have an impact on decreasing the strength of the muscles around the joints. As you get older, the normal walking pattern also decreases. Where at the age of 60, only 85% of the elderly walked in a normal pattern, but at the age of 85, only 18% of the elderly walked in a normal pattern (Munawwarah and Halimah 2020).

The existence of physical disorders causes a decrease in functional activity such as reduced ability to walk and an increased risk of falling in patients with osteoarthritis of the knee related to the length of time the patient has suffered from osteoarthritis of the knee, causing fear of moving and decreasing dynamic balance (Arazi et al. 2021).

The normality test is used to determine the test used in the analysis of research data. The results of the data normality test can be seen in table 2. The normality test uses the Shpiro-Wilk because the sample is <30 respondents. Based on table 2, all groups are normally distributed because $p>0.05$.

The effect of giving exercise on the value of muscle strength, stride length, and dynamic balance is presented in Table 3 and the comparison of the square stepping exercise with the Otago exercise is

presented in Table 4. Based on Table 3 there is an effect of giving exercise in the group that was given the square stepping exercise treatment and in the treatment group that was given the Otago exercise treatment, there was an increase in the values of muscle strength, stride length, and dynamic balance after 5 weeks of training in both treatment groups with a more significant value (p=0.000).

In this study, it can be seen that all groups that were given the stepping exercise treatment and the group that was given the Otago exercise treatment affected increasing muscle strength, stride length, and dynamic balance. Square stepping exercise is a type of exercise with stepping movements and memorizing patterns that causes activation of the lower extremity muscles, both agonists and antagonists, in turn, and increases the process of processing information when making stepping movements (Fisseha et al. 2017). When stepping, muscle contraction occurs, where the shortening of the muscle fibers is facilitated by the presence of energy or adenosine triphosphate (ATP), calcium ions and other proteins so that the muscles can shorten and relax when moving. Muscle contractions that are carried out continuously will increase muscle strength, this can occur due to neurological adaptations that cause changes in the form of increased neuromuscular junction performance, increased motor unit activity and inhibition of the reflex mechanism of the Golgi tendon organ (GTO). So that there is an increase in muscle strength when doing stepping movements in the application of square stepping exercise (Thachil and Thomas 2022).

Improving the sensory system for giving square stepping exercises through repetition of moving forward steps following the exercise pattern provides information about body position related to gravity and the environment as well as the position of each limb with each other. There is also an increase in the neuromuscular and musculoskeletal systems that play a role in controlling body position and motor output. Meanwhile, the central nervous system plays a role in integrating, adapting, and anticipating the balance response. When performing the movement, the postural and lower extremity muscles contract rapidly to return the body's center of gravity to a balanced position. Rapid position changes are mainly compensated by the proprioceptor system of the vestibular system which also reacts very quickly so that it helps maintain body balance by controlling the postural muscles (Sherwood, 2014).

Based on research conducted by Shigematsu, and Rantanen (2008), square stepping exercise is as effective as strength and balance exercise in increasing lower extremity muscle strength. This is also in line with research conducted by Thachil and Thomas (2022) concerning the effect of square stepping exercises in increasing muscle strength, functional walking, and dynamic balance in the female geriatric population.

Table 2. Data Normality Test

Shapiro-Wilk	**30 SCT**	**Meterline**	**TUGT**
	p	**p**	**p**
Square stepping exercise			
PreTest	0.153	0.439	0.196
Post test	0.115	0.402	0.084
Otago exercise			
PreTest	0.117	0.912	0.730
Post Test	0.174	0.965	.0558

Table 3. The effect of training on the value of muscle strength, stride length and dynamic balance

Group	Value PL		Value TUG		Value 30 SCT	
	Mean±SD	***p***	***Mean±SD***	***p***	***Mean±SD***	***p***
Square stepping exercise						
Pre test	0.56±0.07	0.000**	15.57±1.55	0.000**	08.72±1.18	0.000**
Post test	0.66±0.14		9.23±0.78		14.17± 2.33	
Otago exercise						
Pre test	0.56±1.33	0.000**	14.81±0.13	0.000**	08.00±1.90	0.000**
Post test	0.68±0.14		10.22±0.90		15.67±3.47	

Otago exercise is an exercise with balancing movements that will activate movements that are consciously received by sensory nerves in the form of proprioceptors to changes in body position in the joints. This input will be delivered to the brain in the cerebral cortex and then convert sensory information into motor information. Motor information will become motor neurons, causing action potentials in the muscles. The action potential causes the sarcoplasmic reticulum to release large amounts of calcium ions. Calcium ions will cause a force of attraction between actin and myosin filaments resulting in a process of muscle contraction (Tarigan 2018).

In the application of Otago exercise in addition to increasing muscle strength there will also be an increase in flexibility. This happens because when a muscle contracts, it will stretch or stretch the antagonist's muscles. Automatically if someone does strength training it will also affect flexibility, and vice versa (Kocic et. al 2018). Square stepping exercise has a very positive effect on BDNF related to learning and memory in the elderly. The IGF pathway plays an important role in brain development, including angiogenesis and neurogenesis (Westwoo et al. 2019).

Based on research conducted by Theodorakopoulos et al. (2017), stated that strengthening exercises increase muscle strength through the plasticity of the neuromuscular system so that the muscles can adapt to physical activity with a certain intensity. The research by Mahendra et al. (2022) also showed an increase in muscle strength in the lower limbs in older women after 8 weeks of being given an Otago exercise program.

Based on Table 4 between the group that was given the square stepping exercise treatment and the group that was given the Otago exercise treatment with a difference in muscle strength value of 0.50 and stride length (PL) 0.01, the values ($p = 0.492$) and ($p = 0.263$) were obtained, which meant that there was no difference which was significant with the highest mean value of 5.44 in the increase in muscle strength in the group given the square stepping exercise treatment and stride length with the highest mean value of 0.11 in the group given the Otago exercise treatment. Then to increase dynamic balance given the

treatment of the square stepping exercise and Otago exercise with a difference value of 1.75, there was a more significant difference (p = 0.000) with the highest mean value of 6.34 in the group given the square stepping exercise treatment.

Square stepping exercise is an exercise that can improve muscle strength and dynamic balance. Where in this exercise there is sensory activation of changes in body position through mechanoreceptor responses when stepping. This begins with stimulation of the proprioceptive system from the joints to the thickly myelinated nervous system which then provides a sensory response that is forwarded to the somatosensory system and processed in the cerebral cortex to produce motor signals. Then the motor signal will be forwarded to the pyramidal fibers through the lateral corticospinal tract, and the spinal cord which then ends directly in the anterior motor neurons. After this, the anterior motor neuron will conduct an action potential at the axon terminal. The occurrence of an action potential causes the sarcoplasmic reticulum to release large amounts of calcium ions. This will cause an attractive force between the actin and myosin filaments which then results in a process known as muscle contraction (Sasmita, 2020).

Square stepping exercise is an exercise with 3 levels of movement patterns, the first level (beginner), this movement can correct the walking pattern of patients with knee osteoarthritis, and increase proprioceptors in joints, joint capsules, ligaments, and muscles some movements occur and activate muscles around the joints, especially the quadriceps muscles which is the main driving muscle when stepping forward, the second level (intermediate), this movement can increase the center of gravity, line of gravity and bose of support, thereby reducing the risk of falling and increasing dynamic balance and the third level, increasing speed, controlling sudden movements -suddenly in a change of position to further increase self-confidence and improve dynamic balance (Sasmita, 2020).

Based on research conducted according to Vinita et al (2016) that stepping movements and memorizing movement patterns will cause contraction of the lower extremity muscles increasing the musculoskeletal system, this exercise is also able to improve visual abilities, improve memory through visuospatial work walking responses (Shellington et al., 2018).

Otago exercise includes flexibility, strengthening, balance function, and walking exercises. Multi-directional motion from the application of Otago exercise in the treatment group increases muscle strength resulting in hypertrophy with increasing muscle size. The occurrence of muscle contractions when stepping starts from the distal direction to the proximal. At the ankle for forward movement (anterior sway), muscle activation will occur starting from the gastrocnemius muscles, then continuing to the hamstring muscles, and the paraspinal muscles. Whereas for the backward sway response, muscle activation begins with the tibialis anterior muscles, quadriceps.

Table 4. Comparative analysis test of square stepping exercise with otago exercise

Group	Value PL			Value TUG			Value 30 SCT		
	Mean±SD	**Deviation**	**P**	**Mean±SD**	**Deviation**	**p**	**Mean±SD**	**Deviation**	**p**
Square Stepping Exercise	0.10±0.03	0.01	0.263	6.34±1.49	1.75	0.000**	5.44±1.14	0.50	0.492
Otago	0.11±0.38			4.59±1.13			4.94±1.166		

Muscles, and abdominal muscles. Stepping exercises in the application of Otago exercise can increase the basic support (BOS) or fulcrum so that dynamic balance control related to gait and locomotion can be obtained by activating all lower limbs (Kisner, et al 2017).

Based on the clear mechanism, giving square stepping exercises to the treatment group can increase muscle strength by walking forward following three levels of movement using a mat and memorizing walking patterns. Increasingly more and more difficult patterns. Increasing the proprioceptors in joints, joint capsules, ligaments, and muscles against movements that occur activates the muscles around the joints, especially the quadriceps muscles which are the main driving muscles when stepping forward. It can also increase the base of support response, and center of gravity, line of gravity, thereby reducing the risk of falling and improving dynamic balance. Increased speed in controlling sudden movements in changing positions to increase confidence when wanting to move. While the Otago exercise is a flexibility exercise, lower leg muscle strength training with multi-directional motion on the Otago exercise increases the strength of the knee flexor and extensor muscles and hip abduction. Increase the base support (BOS) or fulcrum so that dynamic balance control is related to gait and locomotion.

There are differences in the application of the two exercises to the two treatment groups. Where in the application of Otago exercise there are balance exercise exercises that involve the musculoskeletal and neuromuscular systems on body stability (Tarigan 2018). Meanwhile, the square stepping exercise applies training that requires physical and cognitive abilities, which focuses on improving memory and functional walking. This is what causes the difference in increasing dynamic balance in the application of the square stepping exercise compared to the otago exercise (Ashim 2017).

4. Conclusions

The two treatment groups showed more significant differences in the increase in muscle strength, stride length, and dynamic balance in the administration of square stepping exercise with Otago exercise. Meanwhile, based on the difference in the effect between square stepping exercise and Otago exercise in patients with knee osteoarthritis, it shows that there is no significant difference in increasing muscle strength and stride length, but shows a more significant increase in dynamic balance in square stepping exercise compared to giving Otago exercise.

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