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Effect of proprioceptive exercises on knee joint position sense and balance in patients with knee osteoarthritis

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Abstract
Patients with knee joint osteoarthritis have diminished proprioceptive acuity and balance leading to reduced postural stability thus deteriorating the functional performance of patients with osteoarthritis knee. Muscle weakness, proprioception disorder, high laxity, and excessive movements of the knee during walking have also been reported. These indicate that patients with knee osteoarthritis suffer from knee instability leading to poor balance. Hence the purpose of this study was to find the effectiveness of proprioceptive exercise on knee joint position sense and balance in patients with knee osteoarthritis.
Methods: Sixty people with knee osteoarthritis fulfilled the inclusion criteria and were included in the study. and knee joint position sense was measured using universal goniometer and the balance was assessed using sharpened Rhomberg test (eyes open, eyes closed). Proprioceptive exercises were given for 4 times a week for 4 weeks.
Result: The result of this study showed that there was a significant improvement in knee joint position sense ($p<0.001$) and balance ($p<0.001$) in patients with knee osteoarthritis.
Conclusion: This study concluded that proprioceptive exercise for a period of 4 weeks shows significant improvement in knee joint position sense and balance in patients with knee osteoarthritis.

Keywords: knee osteoarthritis, proprioceptive exercises, balance, knee joint position sense

1. Introduction
Worldwide, osteoarthritis is estimated to be the fourth leading cause of disability [1]. Osteoarthritis of knee increases in prevalence with age and more common in female than in male [2]. It is the second most common rheumatologic problem and it is the most frequent joint disease with a prevalence of 22% to 39% in India. Knee osteoarthritis accounts for 33% compared to other joints. Two types of osteoarthritis are recognized, primary osteoarthritis and secondary osteoarthritis [3].
Typical clinical symptoms are a pain, particularly after prolonged activity, whereas stiffness is experienced after inactivity [2], deterioration of articular cartilage, osteophyte formation, hypertrophy of bone, periarticular muscle weakness that occurs subchondral sclerosis and inflammatory changes in the joint [2, 3]. Pain is the earliest symptoms, coarse crepitus is also accompanied with the swelling of joint that is due to effusion caused by inflammation of the synovial tissue, stiffness is initially due to pain and muscle spasm, but latter capsular contracture and incongruity of joint surface contribute to increased stiffness.
Ageing is associated with a decline in the integrity of the physiological systems that contribute to the control of balance but the presence of knee OA may result in changes that accelerate the deterioration of these systems or compound the effects of ageing [4]. Knee joint proprioception encompasses the sense of joint position and the sense of motion. These senses partially derive from neural inputs arising from mechanoreceptors such as Pacinian corpuscles, Ruffini end organ, muscle spindle, Golgi tendon receptors and receptors in, ligaments and joint capsule). Joint mechanoreceptors have the ability to detect the actual joint position and joint motion [5]. Proprioceptive acuity requires the integrity of all the sensory systems of which, muscle spindle that furnishes sensory information regarding muscle length (joint position sense) and velocity of muscle stretch is considered to be of prime importance. Osteoarthritis (OA) results in changes that affect not only intracapsular tissues but also periarticular tissues, such as ligaments, capsule, tendons, and muscle [5]. Dysfunctional mechanoreceptors in articular cartilage lead to impaired proprioception [6]
The knee joint has been stabilized by a combination of neuromuscular control provided by the muscles and proprioception and passive restriction provided by ligaments and capsule. In patients with knee osteoarthritis, muscle weakness, proprioception disorder, high laxity, and excessive movements of the knee during walking have been reported. These indicate that patients with knee OA suffer from knee instability leading to poor balance, that is due to defect in the neuromuscular system [8]. Balance control relies on sensory inputs from the vestibular, visual and somatosensory systems. Central processing of this information results in coordinated neuromuscular responses that ensure the centre of mass remains within the base of support in situations when the balance is disturbed [8]. Balance consists of maintaining, achieving, or restoring the centre of mass within the base of support [9] that is sensory input from the vestibular, visual and somatosensory systems, central processing of these information results in coordinated neuromuscular responses that ensure the centre

of mass remains within the base of support in situations when balance is disturbed.

Poor balance control, especially during standing or movement, is one risk factor for falls that could be addressed in the knee OA population [9]. Due to all of these impairments, there is a loss of social and functional activities, difficulty in performing self-care activities, loss of work and work-related problems. It also has an impact on emotional well-being, relationships, body image and self-esteem [10]. They suffer increased dependency in walking, stair climbing and other lower extremity tasks [11, 12]. is associated with a decline in integrity in physiological systems that contribute to the control of balance.

Treatment for OA included the use of the individual or combined treatments comprising of electrotherapy, exercise therapy and manual therapy. These interventions were shown to improve proprioception and balance so the use of specific strategies like proprioceptive training may be necessary to individualize the therapeutic program in knee OA patients [13]. Non-pharmacological interventions for knee osteoarthritis is been recommended by ACR that encompasses treatment modes including different exercises for managing pain and other disabilities. [6, 8, 14, 9, 10, 11] These interventions were shown to improve proprioception and balance so the use of specific strategies like proprioceptive training may be necessary to individualize the therapeutic program in knee OA patients [11].

Thus proprioceptive exercise intended to improve balance in patients with osteoarthritis knee [8]. Aero-step equipment is used to provide an unstable base during the performance of the exercise program. Few studies, all utilizing force platforms to measure postural sway, have been undertaken, limited research has evaluated the static postural balance using simple, inexpensive test.

The present study aimed to find the effectiveness of proprioceptive exercises on knee joint proprioception and balance in patients with knee osteoarthritis.

2. Materials and Methods

60 elderly that included 19 males and 41 female between age group 50-75 years, who demonstrated clinical evidence of knee osteoarthritis as described by the American College of Rheumatology classification [13] with numerical pain rating scale (1-5) and pain more than 6 months, patient having score of Sharpened Romberg test less than normative value were included in the study [15]. Subjects on any other exercise protocol as well as subjects suffering from vestibular impairment, neurological conditions that impair balance, vascular impairment, rheumatoid arthritis, polyarthritis or systemic inflammatory arthritis, underwent any knee surgery and lower limb muscle strength less than grade 3 were excluded.

The study was started after obtaining approval from the Institutional Ethical Committee. The patients were fully informed about the treatment procedure and demonstrations were given and written consent was taken. All 60 subjects were assessed for Knee Joint Proprioception sense by using universal goniometer [17]. and Balance using sharpened Rhomberg test [16]. Before starting the intervention.

Exercise protocol consisted of the following

The warm-up exercises included active movements of knee flexion, knee extension, hip abduction, hip flexion, hip extension, trunk rotation (10 repetitions) of each. Active stretching of Rectus, hamstring, gastrosoleus, Adductors (1 set 15sec hold).

Exercise Program

Table 1

Exercise	Week	Repetition	Set
▪ Spot marching on aero-step ▪ Straight lunge on aero-step ▪ Side lunge on aero-step ▪ Half squats on aero-step ▪ One leg balance on aero-step	0 week-2 week 2 week –4week	10 10	2 3

One leg balance on aero-step will be done with hold time according to patients comfort (maximum 30sec)

Cool down exercises were active stretching of Rectus, hamstring, gastroc soleus, Adductors. (1 set 30sec hold).

Breathing exercise- Diaphragmatic breathing (1minute).

The subjects received exercises 4 times a week for 4 weeks. For those patients who were unable to perform the exercises without loss of balance on the equipment were allowed to perform exercises with wall support.

Post-intervention the outcome variables were reassessed [8].

3. Results & Discussion

The purpose of this study was to find out the effects of proprioceptive exercise on balance in patients with knee osteoarthritis. This study also showed a prevalence of female over male, according to Table- 1 patient age ranged from 50-75yrs where mean age was 62.98 with (SD= 8.123), out of which 68.3 % were females and 31.7 were male suggesting that of higher prevalence of females than males. This may be due to male have greater cartilage volume than female the most likely reason is sex hormones and growth factors. Oestrogen, progesterone and testosterone receptors are present in cartilaginous tissue and androgens can stimulate human chondrocyte proliferation as well as collagen and proteoglycans synthesis, post menopause as these factors reduce leaving females more prone to cartilage volume loss and osteoarthritis [18, 19].

Proprioception and balance are key aspects of osteoarthritis treatment as there is a strong correlation with the function of the knee. These deficits, in combination with the ageing process, culminating in greater impairments in balance in this patient population, compared with their age-matched and healthy counterparts [20]. Proprioception information from afferent sensory organs (mechanoreceptors such as Pacinian corpuscles, Ruffini end organ, Golgi tendon receptors and tendon receptors in tendons, ligaments and joint capsule) reaches the central nervous system (CNS), where it is processed and integrated with other signals to regulate neuromuscular control and properly maintain joint stability. Loss of proprioception may be expected as a result of laxity of the capsule and ligaments caused by bone height and loss of cartilage. Also, the possible release of lytic enzymes around the joint may cause damage to the receptor end-organs within the capsule [22]. Articular mechanoreceptor's afferent fibers also project onto gamma-Motor neurons in the spinal cord. Gamma-Motorneurones activate the intrafusal muscle fibers that makeup muscle spindles. Thus gamma-motor neuron excitability governs muscle spindle sensitivity. If arthritic damage to articular mechanoreceptors evokes sensory input that reduces gamma-motor neuron excitability, this would decrease

muscle spindle sensitivity and consequently decrease proprioceptive acuity and thus impairs balance [23]. As proprioception and muscle strength are associated with knee OA and thus may be postulated as a cause of impaired balance. It has been well established that individuals with symptomatic knee OA have weaker quadriceps [29] and lower limb muscle strength. Atrophy muscle weakness may decrease muscle spindles sensitivity, thereby possibly impairing proprioceptive accuracy [23].

According to Table-2, proprioceptive exercises were shown statistically significant improvement in pre-post values of unilateral and bilateral knee joint position sense. This may be due to the generation of proprioceptive responses by the somatic senses when the patient performs balance-keeping exercises on unstable surfaces. These responses bring about adjustments in the lengths and tension levels of various muscles and also alter the position of the joints to facilitate joint movement [12]. Proprioceptive exercises expose the patient to activities that challenge the stability of the knee and balance in a controlled manner during rehabilitation [24]. Proprioceptive exercises are also assumed to provide further tactile sensation from the sole of the foot which contribute to greater sensorimotor input and optimize joint reposition during training. Accuracy at the muscle spindle is through repeated motion can lead to cortical reorganization to re-enforce the assessment of proprioceptor's accuracy [25]. Proprioceptive exercises facilitate knee joint proprioceptors by increasing intraarticular pressure and thereby stimulating Ruffini nerve endings, which are sensitive to changes in intracapsular fluid volume [26].

Although proprioceptive exercise does not change the number of mechanoreceptors, it induces morphological adaptations in the muscle spindle at the peripheral level. The latency of stretch reflex responses decreased and the amplitude increased due to micro level adaptations at muscle spindles Exercises and physical activity may be one of factor to modulate joint position sense by excitation of activity of muscle spindle in non contractile unit of muscle fibers and plastic alteration of central nervous system such as increased strength of synaptic connections and/or structural changes in the organization in cortex which leads to enhanced joint proprioception [27]

According to Table-3, there was statically significant improvement observed in balance by using sharpened Rhomberg test (Eyes open P= <0.001, Eyes closed P=<0.001). Proprioceptive exercises increase the coordination between muscle groups and improve the response to sensorial information as the patient progresses through exercises to different postures, BOS and challenges to their centre of gravity. So each exercise will elicit automatic and reflexive muscular stabilization demanding the patient to maintain balance under various situations [28]. Proprioceptive exercise on unstable surface improves balance by stimulating Golgi tendon organs and muscle spindles following joint movement, increasing muscle activity and muscle competency, receiving greater stimulation of proprioceptors and mechanoreceptors in and around the knee joint thus enhancing balance ability [20]. The afferent feedback from the receptors include Ruffini endings, Pacini corpuscles, free nerve endings, Golgi tendon organs, and muscle spindles generally considered to provide the central nervous system with important feedback for knee stability, these proprioceptive fibres, together with the ligaments and muscles, combine to create reflex arcs that play a vital role in knee stability leading to postural control by providing feedback between the central nervous system (CNS) and the joint. The cerebellum receives sensory input from joint position sensors, muscle spindles, and the joint capsule, which generates neurological feedback in response to the joint movement which aids in maintaining joint stability [29]. Proprioceptive exercises improve the ability of the person's control over joint movements in all positions by providing increased motor control through a reflex route thereby maintaining body balance [30].

Several potential mechanisms may be responsible for the balance deficit observed within the OA. As for effective control of balance not only accurate sensory input but also the timely response of strong muscles are important and thus may be postulated as a cause of impaired balance [4]. Therefore, this exercise program strengthens the lower limb muscles, that enhance the balance ability [8]. This study included exercises that were done on the aero step and balance exercise on an unstable platform was effective in improving proprioception and enhancing leg muscle strength [31]. As during forwarding lunge position the targeted muscles include quadriceps, gluteus along with the hamstrings activation. During side lunge, the targeted muscle is hip adductors, hip abductors along with quadriceps. While in half squats there is activation of gluts, quadriceps, hamstring. Thus a combined effect of proprioceptive exercises with the strengthening of lower limb muscle could be a possible reason for the improvement in balance in patients with knee osteoarthritis [8].

This study used aero-step equipment it prevents any large shocks to the knee joint, changes the neuromuscular recruitment pattern of knee joint muscle, stimulation of proprioceptors and more smooth stimulation of the mechanoreceptors thus enhancing the balance ability [20]. Aero-step equipment enables exercise in a narrow space and is easy to handle. Due to the nature of the balloons filled with air, it prevents any large shocks to the body [20]. Balance exercise on an unstable platform changes afferent input in the central nervous system and promotes postural control and dynamic balance more than balance exercise on a stable platform [29].

The results of this study are in accord with a study by Monika Moitra and Sonali Sharma concluded that proprioceptive training along with conventional physiotherapy show statistically significant improvement in balance and proprioception in knee osteoarthritis patients [34]

Another study was conducted by Kaur Rajendra also found that proprioceptive exercises are beneficial in improving the joint position sense using universal goniometer in patients with osteoarthritis. The study also concluded that proprioceptive exercises help in reducing pain and functional disability [27].

Thus in this study, there was significant improvement observed in knee joint position sense and balance following proprioceptive exercises as it improves knee joint position sense and maintains balance by improving knee stabilit

Table 1: Demographic characteristics of the study participants (N=60)

Variables	Sub-groups	N	%
Gender	Male	19	31.7
	Female	41	68.3
Age (Mean ± SD)		62.98 ± 8.123	

Table 2: Comparison of the effect of proprioceptive exercises on knee joint position sense by using universal goniometer in terms of {Mean (SD)} pre and post in those with unilateral and bilateral knee osteoarthritis using paired t-test

	Group	N	Mean	Std. Deviation	t value	P value
Unilateral	Pre	30	11.93	3.591	9.865	<0.001**
	Post	30	9.07	2.993		
Bilateral	Pre	30	12.38	2.762	16.442	<0.001**
	Post	30	9.08	2.165		

Table 3: Comparison of the effect of proprioceptive exercises on balance by sharpened Rhomberg test in terms of {Mean (SD)} pre and post in eyes opened & closed situation using a paired t-test

	Group	N	Mean	Std. Deviation	t value	P value
Eyes opened	Pre	60	19.361	6.029	18.011	<0.001**
	Post	60	27.637	7.446		
Eyes closed	Pre	60	9.573	4.408	12.103	<0.001**
	Post	60	14.629	4.919		

4. Conclusions

We conclude that proprioceptive exercise for a period of 4 weeks shows significant improvement in knee joint position sense and balance in patients with knee osteoarthritis.

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