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Effect of closed versus open kinetic chain exercise to improve knee muscles strength and balance in elderly population: A hypothetical literature review

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Abstract
Background: Chronic knee pain is becoming a significant social issue with ageing. The loss in muscle strength and balance with increasing age often lead to physical and quality of life impairments, as well as increased morbidity. Since knee pain and impaired balance are major issues affecting the quality of life of the elderly population, a preventive approach is required to decrease the incidence of muscle weakness and decrease proprioception. Objective to compare the effectiveness of open kinetic-chain (OKC) and closed kinetic-chain (CKC) exercise in improving the elderly population's knee strength and balance. **Method:** A literature review was done where number of previously published articles were searched from various online platforms to find the effectiveness of OKCE versus CKCE in improving knee muscle strength and balance in elderly population. Result Both CKCE and OKCE were found to improve strength in lower leg musculature but OKCE are comparatively more effective strength training program. However, when it comes to improving balance and proprioception, CKCE were found to be more effective. **Conclusion:** OKCE are better strengthening exercise regimes whereas CKCE are better choice of exercise regimes when it comes to improving balance and proprioception.

Keywords: Knee pain, balance, elderly population, open kinetic-chain exercise, closed kinetic-chain exercise

Introduction
The most significant development in the field of public health in the 21st century is the great rise in the elderly population worldwide [1]. Chronic pain, especially knee pain, is becoming a significant social issue with ageing, causing physical and quality of life impairments, as well as increased morbidity. Knee pain incidence varies by country and race, but about 23 percent to 48 percent of the world's elderly population suffers from knee pain [2]. Recent estimates of the Global Burden of Disease have shown that knee OA is the fastest rising major health condition and the second leading cause of disability globally [3]. The overall prevalence of knee OA in India is 28.7 percent, according to a report by Prakash *et al*. in 2016 [4]. Knee OA has been found to be more common in women (31.6 percent) than in men (28.1 percent). In older populations, the risk of OA-associated impairment is equivalent to that of cardiac disorders [5] and more frequent than any other medical issue [6]. Although previous studies have revealed multifactorial risk factors for knee pain, including obesity, radiographic changes, female gender, older age, stiffness and previous knee injury, the underlying etiology for knee pain remains poorly understood [2, 7]. The loss in muscle strength with rising age is one of the major issues responsible for knee pain. One of the major knee joint stabilizing muscles is the muscles around the knee, especially the quadriceps femoris muscle. With age, these muscles are likely to get weaker. The atrophy of these muscles, combined with age, results in knee pain and functional disability. It can relieve pain and contribute to a better quality of life by doing exercises to strengthen these muscles [8]. Decline in postural stability, gait, and balance with age is another major issue, apart from reduced muscle strength [9]. While different factors are correlated with falls, some of the most significant intrinsic fall risk factors in community-dwelling populations have been established as gait and balance deficits [10]. Proprioception was defined as "the perception of joint and body movement as well as position of the body, or body segments, in space", [11] and it is considered as the most important sensory system in the maintenance of postural stability in

the elderly people [12]. In addition to contributing to knee pain, muscle strength loss has also been shown to be linked to diminished proprioception [13]. The decline in proprioception of the lower limb was associated with balance issues observed in the elderly, which were, in turn, associated with a higher rate of falls [14]. Falls are today considered to be one of the most severe geriatric problems, with high incidence, morbidity and mortality rates.

Since knee pain and impaired balance are major issues affecting the quality of life of the elderly population, a preventive approach is required to decrease the incidence of muscle weakness and decrease proprioception. Two types of physical exercises, open kinetic chain exercises (OKCE) and closed kinetic chain exercises (CKCE), are used to strengthen the knee joints. The distal portion of the lower limb is free to move during movement in open kinetic chain exercises. The hand or foot will move freely in OKCE, usually in response to movements of the elbow or knee joint that cause motion during non-weight bearing (NWB) support. Weight on the distal extremities can be added [15, 16]. During the closed kinetic chain exercises, by comparison, the distal portion of the lower limb is fixed. The hand (arm movement) or foot (leg movement) stays fixed during CKCE when doing an exercise. The hand or foot is placed on the ground and remains in contact with the surface of the apparatus [17]. The exercises in the closed kinetic chain are closely linked to the tasks we conduct in everyday life and more practical in nature [18, 19]. The relative effectiveness of open kinetic-chain (OKC) and closed kinetic-chain (CKC) exercise to improve the strength and regulation of the muscles of the knee is strongly debated. [20]. This led to uncertainty that whether CKCE or OKCE is beneficial in improving the elderly population's knee strength and balance and this literature review was carried out to analyze the same.

Method

The main aim of this study was to find the effectives of OKCE versus CKCE in improving knee muscle strength and balance in elderly population. In this literature review, number of previously published articles were searched from various online platforms including Pub Med, Cochrane and Elsevier and analyzed to determine the benefits of OKCE and CKCE and their superiority on one another. The primarily used keywords during the search were "Knee Pain", "Osteoarthritis", "Open Kinetic Chain Exercise", "Close Kinetic Chain Exercise", "Balance", "Fall" and "Muscle Strength". Due to the lack of literatures available on effect of OKCE and CKCE on healthy elderly, studies conducted on elderly subjects suffering from strength and balance impairment have been incorporated in the review.

Cho *et al*. conducted a study in 2014 to examine the effects of closed kinetic chain exercises (CKCEs) and open kinetic chain exercises (OKCEs) with elastic bands on the electromyographic activity of patients with degenerative gonarthritis. He concluded that while both CKCEs and OKCEs using elastic bands are substantially more effective in strengthening lower extremity muscles than quadriceps strengthening exercises, OKCEs were found to be more beneficial for patients with restricted ranges of joint motion and should be recommended as a single joint exercise. In early stage muscle strengthening activities, in individual muscle training, and in multi-joint exercises, OKCE has also been beneficial. For stabilization and practical training, CKCEs have been found to be more appropriate [21].

Similar result was obtained in a study performed by Ojoawo *et al*. in 2016. He concluded that along with improving the muscle strength, closed kinetic chain exercise could also improve joint proprioception, muscle strength, and balance. According to him, walking which is form of CKCE is excellent way to reduce pain and disability in people with knee OA. [22] A moderate effect of walking compared to home-based quadriceps strengthening exercises on knee pain and function was reported in the previous systematic review conducted by Roddy *et al*. in 2005 as well [23].

A study by Kwon *et al*. who assessed effect of open and closed kinetic chain exercise in 2013 concluded that closed kinetic chain exercises generate the co-contraction of the agonist and antagonist muscles to provide a greater articular stability, they also increase the proprioception. He believed that the feedback is more efficient due to the body compressive forces and the contact of the foot with the ground, besides the production of functional movements of the lower limb through concentric and eccentric contractions of the muscles involved in the joint movements of the hip, knee and ankle, activity commonly performed in daily activities [24]. Similarly according to Lee *et al*. in 2013, CKCE may provide more sensory feedback and hence improve the sensorimotor functions, including motor control and joint proprioception, to a greater extent than OKCE [17]. His study showed that in the CKCE and OKCE groups, muscle activity of the rectus femoris and biceps femoris was significantly increased relative to the control group. However, gastrocnemius and anterior tibialis muscle activation in the CKC exercise group alone was significantly increased relative to the OKC exercise and control groups. It is likely that the CKC exercise will help simultaneously strengthen the quadriceps and hamstrings while still using the hip and ankle joints. Therefore, this will provide input from the entire lower extremity (instead of merely from the exercised joint in the OKC exercise) and thus increase the activation of the mechanoreceptors around the joint and the firing muscle spindles [25].

When it comes to improving strength, Tagesson *et al*. in 2008 concluded that OKCE might be more useful than CKCE and conventional therapy for increasing the knee extension strength. In his study conducted on patients with knee osteoarthritis, a Non Weight Bearing (NWB) exercise group demonstrated improved knee extensor strength. [26] According to Lee *et al*. in 2013, NWB exercises mostly affect the isolated knee extensor muscles, as they are performed from 90° of knee flexion to full extension with concentric quadriceps action, followed by flexing of the knee joint to the starting position with eccentric quadriceps action. This differs from normal knee extension with concentric quadriceps, followed by knee flexion with concentric hamstrings. This may explain why the NWB exercise observed greater changes in knee extensor strength. The study also found that the OKCE and CKCE groups showed significantly improved knee JRS compared to the control group, but CKCE was more successful than OKCE in increasing proprioception in the weight bearing test [27].

The findings were similar to the previous study by Jan *et al*. who conducted a study in 2009 to find the effects of weight-bearing versus nonweight-bearing exercise on function, walking speed, and position sense in participants with knee osteoarthritis concluded that while both WB and NWB exercises had positive result on strength, WB exercise improved position sense, which may enhance complex walking tasks [28].

Another study by Md. Saddam Hossain in 2017 to find out the effectiveness of close kinetic chain exercise versus open kinetic chain exercise in patients with knee joint found that Close Kinetic Chain exercise along with traditional physiotherapy

was better treatment than Open Kinetic Chain exercise along with conventional physiotherapy alone for reducing pain and impairment in patients with osteoarthritis [29].

A study by Gamal Salaheldin in 2014 concluded that closed-kinetic chain exercise significantly improved knee joint position sense and open-kinetic chain exercises improved isometric quadriceps strength while there was no difference between exercises in improving functional walking in patients with hemophilic arthropathy. [30] Similarly, Gbiri *et al*. performed a study on OA knee subjects to compare the efficacy of OKCE and CKCE. He concluded that in people with knee osteoarthritis, both open-chain and close-chain kinematics enhance functional performance and minimize symptoms and severity. But close-chain kinematics are more efficient in enhancing the functional efficiency of proprioception in people with knee osteoarthritis. [31]

In a 2004 study by Alghadir *et al*. who conducted a study to examine the impact of combined CKCE and OKCE on OA subjects, the result seemed to be that CCEs (Combined Chain Exercise) were more effective for pain relief in patients with knee OA than either OKCEs or CKCEs. For the use of CCEs, Alghamdi *et al*. argued that clinicians should not discard CKCEs in knee OA management and the use of OKCEs alone in knee OA management undermines the specificity and selectivity principles of training that state that when the exercise most closely resembles the task, optimum gains are made in a motor activity. [32] Similar results were obtained in the study conducted by Olagbegi *et al*. in 2017 who conducted a study to investigate and compare the effectiveness of twelve-week open, closed and combined kinetic-chain exercises (OKCEs, CKCEs and CCEs) on pain and physical function in the management of knee osteoarthritis [33].

Result

Total 13 articles were reviewed in this study with their publication dates ranging from 2004 to 2017. Among the 13 articles, 11 of them were Randomised Controlled Trials, 1 of them was Systemic Review and 1 of them was Review. All of the studies were done to assess the efficacy of CKCE and OKCE to improve knee muscle strength and balance. After reviewing the articles, the analysis shows that while both CKCE and OKCE are found to improve strength in lower leg musculature, OKCE are comparatively more effective strength training program. But when it comes to improving balance and proprioception, CKCE are found to be more effective and OKCE plays a very small role in improving proprioception. Due to lack of research done on asymptomatic elderly population, it is difficult to deduce the effect of OKCE and CKCE in prevention of the onset of muscle weakness or balance impairment as the age progresses.

Discussion

Given the present scenario, there is exponential increase in elderly population who are in need of physiotherapy treatment for issues regarding their balance and muscle strength. Since old age is physiologically as well as pathologically prone to developing knee pain, it is important to address the issue, the sooner, the better. The major cause of knee pain is reduction in knee muscle strength in elderly. Not only that, reduced muscle strength is also found to impact balance.

According to a study by Anwer *et al*. reduction in pain and consequent improvement in function following quadriceps strengthening exercise was due to improved flexibility of the knee joint, which is strengthened by improvement in muscle strength of the quadriceps [34]. Literature evidence also indicates that reinforcing quadriceps can stimulate the pain-suppressing β-endorphin system, favorably alter the sensory feedback to the central nervous system and the gate control mechanism (regulating the perception of pain), and also enhance the blood flow and cartilage nutrition [35]. The musculature of the legs is known to play an integral role in knee joint stability, loading, proprioception, and functional motion [36]. Since muscle power represents the product of muscle strength and movement speed, and is a superior determinant of human locomotion and physical function compared to strength, dynamic knee stability can be greatly compromised by impairments in muscle power, which contribute more to inadequate control of tibial translation during ambulation, leading to damage and ultimately knee pain. Similarly, the ability of the musculature to dissipate knee joint loads can also be more seriously restricted by muscle strength impairments, thereby raising the risk of articular contact stress, leading to pain. Second, lower limb muscles with impairments in maximal contractile velocity, rather than impairments in the development of muscle force, can fatigue more rapidly [37], resulting in poor overall neuromuscular control, which may enable pathological joint movement and painful loading of the articular structures [36].

Sarcopenia, which is defined by decreased muscle mass and impaired muscle function progresses with aging and is associated with frailty, falls, mortality, and pain risk [38]. According to a study conducted by Cheon *et al*. [39] reduced muscle mass and strength in the lower extremities was an independent risk factor for knee pain in both the general population and in knee OA participants. DLEM was, however, positively linked to the magnitude of pain. With age, body structure changes, including decreased muscle mass or strength and improved fat proportions. In their mid-twenties, most adults reach their peak muscle strength and retain this degree of strength reasonably well until the sixth decade [40]. This decline in strength is consistent across muscle groups and all types of measurements – isometric strength (when the limb does not move), concentric strength (when the muscle shortens), eccentric strength (when a lengthening contraction occurs) and when strength is measured isokinetically (at a fixed speed) [41]. In the ageing process, the pathophysiology of strength and muscle mass loss is complex. The loss of muscle mass is caused by decreased muscle fiber and motor unit numbers and decreased muscle fiber size [42]. Apoptosis starts if muscle fibres reach the critical minimum size. Denervation and neuron loss are other causes of apoptosis during the ageing period [43]. In addition, strength capacities per motor unit decreases. Muscle fiber loss decreases strength, decreases muscle metabolism, and increases the risk of muscle injury. The rate of synthesis of muscle protein decreases with age. In addition, with increased age, muscle repair capabilities are diminished. [44] The decline of anabolic hormones, resulting in a catabolic effect on muscles and bones, is another significant cause of strength and muscle mass loss during the ageing process. The reduced hormone levels of testosterone, dehydroepiandrosterone, growth hormone, and insulin-like growth factor-I play a main role in this process [45]. About the 50^{th} life year hormonal status of human body is changing. In men andropause takes place in this time period. The menopause of women begins between 45^{th} and 55^{th} life year. The decline of hormonal synthesis leads to distinct changes in human body with decreasing muscle mass and strength [42].

Since the leg musculature modifies the knee loading environment, there has been a great deal of interest in the function of muscle parameters, especially knee osteoarthritis,

in knee pain. Several cross sectional studies of knee OA have shown that increased pain is associated with decreased muscle strength [46]. Multiple theories exist concerning the association between DLEM (Decreased Lower Extremity Mass) and the severity of knee pain. First, muscle mass is a major determinant of muscle strength and is important throughout the joint for the distribution of pressure. Therefore, DLEM may aggravate knee pain via muscle weakness which diminishes the ability to disperse load across the joint, and decreases shock absorption [47]. Second, impaired proprioception (joint position and movement awareness) is also associated with knee pain. Muscle mechanoreceptors may be affected by decreased lower extremity muscle mass (DLEM), thus reducing proprioceptive acuity [48]. Other studies have also found relationship between reduced muscle mass and impaired proprioception. The reduction in muscle mass not only causes muscle strength to decline, but also contributes to a reduction in intrafusal muscle fibres and, eventually, muscle spindles responsible for proprioception [49]. Thirdly, pro-inflammatory cytokines, including tumor necrosis factor-alpha, interleukin (IL)-1, and IL-6, can induce myofibrillary protein breakdown when muscle mass is reduced. This chronic low-grade inflammatory condition will increase the peripheral sensitization and central sensitization of muscle nociceptive afferent neurons, contributing to a stronger response to pain [50].

Numbers of therapeutic exercises are often used to improve physiological impairments such as reduced joint motion, muscle weakness, impaired balance, disability, and proprioception OKCE and CKCE have both advantages and disadvantages; however, in recent years CKCE have been more frequently recommended. The reason for this preference is that CKCE include more functional tasks. [17] When we review the past literatures, it is seen that many of the studies incline towards OKCE when it comes to improving strength. But when it comes to improving balance, the studies are found to favor CKCE over OKCE.

OKCE has a restricted range of motion and is known to be an important exercise in strength training [15, 16]. In addition, OKCE aims to maintain the shape and strength of additional training [51] and OKCE mainly targets concentric muscle contraction as well as the generation of increased traction and rotational forces and provides stability through external means [15]. In addition, acceleration increases, resistance decreases, distraction force and torque are lost during OKCE, and increased strain is imposed on the mechanoreceptors of the joints and muscles, while concentric acceleration and deceleration are correlated with an increase in efferent functional characteristics such as activity promotion [52]. According to Irrgang *et al*. improvements in daily function would be best served by exercise resembling the daily activity. The specificity of such exercises (OKCE) must also be geared toward mainly strengthening instead of improving a specific functional activity; while issues relating to exercise extend beyond simple consideration of cartilage wear and tear [53].

The dynamic stability of the muscle contraction prevails over the simultaneous eccentric contraction in closed-chain movement, and the pressing joint shear force decreases the intrinsic stability, thus sensitizing the capsule mechanoreceptors to changes in pressure and fostering proprioception. CKCE also strengthens the antagonist of the damaged target to influence the stability of the joint [17]. CKCE is thought to improve the proprioception of the knee joint by increasing intra-articular pressure and thereby stimulating the endings of the Ruffini nerve, which are responsive to changes in the volume of the intracapsular fluid. By approximating the joint and stimulating Golgi ligament endings and muscle spindles, the proprioceptive feedback in CKCE helps protect the joint and minimize ligament strain. It also helps people to conduct rehabilitative exercises with the knee in a more usable position that can mimic everyday life activities [54]. In one of the studies by Vallbo *et al*. CKCE was found to cause a greater stretch of the calf muscle than in OKC exercise, thus increasing afferent information from the muscle spindle and Golgi tendon organs of the calf muscles; the CKC procedure involves a more eccentric strength of the knee extensor to stabilize the motion than the OKC procedure, thereby recruiting more motor units and triggering more muscle spindles [55].

Conclusion

This literature review concludes that OKCE are better strengthening exercise regimes. Since they focus on individual muscle group, they help in recruiting maximum muscle fibres. Whereas CKCE are better choice of exercise regimes when it comes to improving balance and proprioception. Also, CKCE mimic the activities of daily life so they help to train the muscles and joint receptors in a needful pattern. This study also concludes that we are in dire need of further researches to be done on asymptomatic elderly population to assess the effect of various therapeutic exercise protocols that will help to delay the onset of symptoms impairing their strength and balance. The studies on preventive exercises could help us reduce the higher incidences of knee pain and occurrence of falls in old aged people thus improving their quality of life and reducing the burden on Global Healthcare System.

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