T.C.
YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF PHYSIOTHERAPY AND REHABILITATION

THE EFFECTS OF CYCLE ERGOMETER WITH BIOFEEDBACK ON DEEP SENSATION IN ELDERLY PATIENTS WITH KNEE OSTEOARTHRITIS

MASTER OF PHYSIOTHERAPY THESIS

NİLAY ARAL, PT

İSTANBUL
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This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by the Administrative Board of Institute with decision dated .....24 July 2023..... and numbered .....

Prof. Dr. Bayram YILMAZ

Director of Institute of Health Sciences

DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material that has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

Nilay ARAL, PT.

DEDICATION

I would like to dedicate my thesis to my beloved and loving parents Nesrin Aral, Oktay Aral, to my brother Doğaç Aral who always supported me and to my dear helpful friend Kaan Kurtoğlu.

Nilay ARAL

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LIST OF SYMBOLS AND ABBREVIATIONS

6MWT	6 Minute Walking Test
AAOS	American Academy of Orthopaedic Surgeons
ACL	Anterior cruciate ligament
AL-TENS	Acupuncture-like TENS
AP	Anteroposterior
CEG	Cycle Ergometer Group
CG	Control Group
CNS	Central Nervous System
ECM	Extracellular matrix
FT	Femorotibial
GBD	Global Burden of Disease
HADS	Hospital Anxiety Depression Scale
HRR	Heart rate reserve
IHME	The Institute of Health Metrics Evaluation
KO	Knee osteoarthritis
MRI	Magnetic resonance imaging
NMJ	Neuromuscular junction
NSAID	Non-steroidal anti-inflammatory drugs
NWB	Nonweight-bearing
OA	Osteoarthritis
PASE	Physical Activity Scale for the Elderly
PTOA	Post-traumatic osteoarthritis
ROM	Range of Motion
SF-12	Quality of Life Short Form-12
SMD	Standardized mean difference
STT	Spinothalamic tracts
TCS-11	Tampa Kinesiophobia Questionnaire Short Form
TENS	Transcutaneous Electrical Nerve Stimulation
UK	United Kingdom
USA	United State of America
WB	Weight-bearing
WOMAC	The Western Ontario and McMaster Universities Arthritis Index

ABSTRACT

Aral, N (2023). The Effect of Cycle Ergometer with Biofeedback on Deep Sensation in Elderly Patients with Knee Osteoarthritis.

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The purpose of the research is to determine the effects of Cycle Ergometer with Biofeedback on deep sensation, physical condition, and body awareness on patients with knee osteoarthritis (KO). Totally 25 volunteers were involved in the study, and they were divided into Cycle Ergometer Group (CEG) (n=12) and Control Group(CG) (n=13). Patients with KO with a Kellgren-Lawrence scale between 1-3 were included in the study. Before the volunteers attended the study, they were examined by the physician and referred to physical therapy. Patients were assessed with Demographic Information Questionnaire, Diapason, Digital Goniometer, Physical Activity Scale for the Elderly (PASE), 6-Minute Walking Test (6MWT), The Western Ontario and McMaster Universities Arthritis Index (WOMAC) before and after interventions. Transcutaneous electrical nerve stimulation (TENS) and ultrasound were applied to all patients. Isometric exercises were performed on all patients five times a week for three weeks. TENS was used as modulated tens for 20 minutes. Ultrasound was used for 5 minutes. Isometric exercises are included for the lower extremities. In addition, the Cycle Ergometer group performed pedaling on the Cycle Ergometer for 20 minutes five times a week for three weeks. The study results showed statistically different vibration, PASE and WOMAC values compared to groups($p<0.05$). CEG has higher effects at the end of the intervention. Moreover, 30-degree, 90-degree, 6-MWT, PASE, and WOMAC scores are statistically improved after the intervention in both groups ($p<0.05$). However, CG has any statistical improvement on Dipason and 60-degrees ($p>0.05$). As a result, Cycle Ergometer with Biofeedback can improve individuals' knee proprioception and physical activity levels and decrease conditions caused by osteoarthritis.

Keywords: Cycle Ergometer, Biofeedback, Knee osteoarthritis, Deep sensation, Body awareness, Proprioception

ÖZET

Aral, N (2023). Biofeedback Bisiklet Ergometrisinin Diz Osteoartritli Yaşlı Hastalarda Derin Duyu Üzerine Etkisi.
Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Fizyoterapi Anabilim Dalı Yüksek Lisans Tezi, İstanbul.

Bu çalışmanın amacı geri bildirimli bisiklet ergometresinin gonartrozlu bireylerde derin duyu, titreşim ve pozisyon algısının ve vücut farkındalığının üzerine etkisini belirlemektir. Çalışmaya 25 gönüllü katılmış ve Bisiklet ergometresi grubu (BEG), (n=12) ve kontrol grubu (KG), (n=13) olarak ayrılmıştır. Toplamda Kellgren-Lawrence skoru 1-3 arasında olan kişiler çalışmaya dahil edilmiştir. Gönüllüler çalışmaya katılmadan önce doktor tarafından muayene edilip yönlendirilmiştir. Hastalar Demografik Bilgi Anketi, Diyapazon, Dijital Gonyometre, Yaşlılar için Fiziksel Aktivite Ölçeği, 6 Dakika Yürüme Testi ve The Western Ontario and McMaster Universities Arthritis Index (WOMAC) ile tedavi öncesinde ve sonrasında değerlendirilmiştir. Tüm hastalara haftada 5 gün 3 hafta boyunca Transcutaneous electrical nerve stimulation (TENS) ve ultrason uygulandı ve izometrik egzersizler yaptırıldı. Tens, 20 dakika boyunca modulated tens olarak uygulandı. Ultrasound 5 dakika boyunca kesikli modunda uygulandı. İzometrik egzersizler alt ekstremitelere uygun olacak şekilde yapıldı. Ek olarak Bisiklet Ergometresi grup(BEG) 3 hafta, haftada 5 gün bisiklet ergometresinde 20 dakika pedal çevirmiştir. Çalışmanın sonucunda titreşim, PASE ve WOMAC değerlerinde gruplara göre istatistiksel olarak anlamlı farklılık olduğu görüldü ($p<0.05$). BEG çalışmanın sonunda daha yüksek skorlara sahipti. Ayrıca derin duyu değerlendirme sonuçları, 30 derece, 90 derece, 6DYT, PASE ve WOMAC puanları müdahale sonrası her iki grupta da istatistiksel olarak iyileşmiş bulundu ($p<0.05$). Ancak kontrol grubu, diyapazon ve 60 derecede istatistiksel olarak gelişme göstermemiştir.($p>0.05$). Sonuç olarak geri bildirimli bisiklet ergometresi, yaşlı bireylerin diz propriosepsiyonu ve fiziksel aktivite düzeylerini iyileştirebildiği gibi osteoartritin neden olduğu durumları da azaltabilir.

Anahtar Kelimeler: Bisiklet Ergometresi, Biofeedback, Diz osteoartriti, Derin Duyu, Vücut Farkındalığı, Propriosepsiyon

1. INTRODUCTION AND PURPOSE

Osteoarthritis (OA) can be identified as a joint failure that causes pain due to disrupting the harmony between synthesis and destruction of the extracellular matrix, articular cartilage, and subchondral bone [1]. Osteoarthritis may also lead to destruction of the joint cartilage, with its deterioration due to mechanical, biological, and enzymatic reasons that increase the pain [2].

The incidence of OA ranges from 14.6/1000 person-years in Canada and 40.5/1000 person-years in the United Kingdom. [3]. Research of The Institute of Health Metrics Evaluation (IHME)'s Global Burden of Disease (GBD) showed that 10.5% of the United States population has OA and that this figure increases with years. A study conducted in the United Kingdom showed that osteoarthritis is more common in females than males and increases with age, especially after age 40. In addition, the prevalence has increased at a rate of 1.4% per year since 1998, when the incidence is declining at a rate of -1.6% per year [4]. Moreover osteoarthritis mostly occurs on the knee joint. Losina et al showed that the lifetime risk of diagnosed symptomatic knee OA is 13.8% in the USA [3].

One of the initial risk factors for KO are female gender, family history, and aging. Aging is an important risk factor because it causes loss of proprioception and muscle strength. Furthermore obesity, low bone mineral density, trauma, physical inactivity, joint alignment disorder, and poor eating habits can also increase the frequency of KO [5,6]. The lack of proprioception has significant places in the development of osteoarthritis. Because proprioception disorder may result in inaccurate neuromuscular control and destabilization of the knee joint; therefore a structural disorder of mechanoreceptors can occur. This deterioration disrupts the load distribution on the articular cartilage that provokes osteoarthritis. The sensory information which comes from muscles, tendons, joint capsules, ligaments, connective tissues, and afferent signals of skin receptors are essential for the proprioception of the patellar area. Muscle spindles, which depolarize when extrafusal fibers are stretched, and Golgi tendon organs, which notice localized muscle contraction, are two examples of musculotendinous proprioceptors. Potentials generated by the stimulation move from the cerebellum to the spinal cord through the dorsal root and the spinocerebellar tract. In addition to proprioceptors Pacinian corpuscles, which adapt quickly, sense of joint

motion, while Ruffini receptors and Golgi receptors, which adapt slowly, sense of joint position. From these articular receptors, sensory information is transferred by the articular nerves and enters the spinal cord via the dorsal roots before proceeding to the thalamus and sensory cortex or to the cerebellum via the spinocerebellar tract.

Proprioception is an important sense for body perception, to be able to perform our daily life activities in a proper pattern, such as walking, sitting, holding something [7,8,9]. Age and decreased knee proprioception sense are extremely strongly correlated. Moreover it is very common to experience pain and inactivity due to proprioception disorder in older ages [7]. A study conducted with gate analysis showed people with mechanical knee pain had more significant angular acceleration before heel strike and therefore hit the ground much harder. The apparent reasons for this result are that the quadriceps of these patients are less active and have shorter quadriceps activation time [10].

As a result, KO and loss of deep sensation affect the quality of life of elderly people. Therefore, this study examines the effect of a Cycle Ergometer with Biofeedback on proprioception in older people with KO.

Hypotheses:

H0: Cycle Ergometer does not improve the deep sensation of individuals with knee osteoarthritis.

H1: Cycle Ergometer improves the deep sensation of individuals with knee osteoarthritis.

2. THEORETICAL INFORMATION AND LITERATURE

2.1. Osteoarthritis

According to the Osteoarthritis Research Society International, osteoarthritis (OA) is initially characterized by abnormal metabolism of joint tissue at the molecular level. It is followed by structural or functional changes in the joint, including cartilage degradation, bone remodeling, formation of bony outgrowths (osteophytes), inflammation of articulation, and ultimately loss of normal joint function, which can lead to illness.

In the joints that are affected by osteoarthritis, various pathological changes can be observed, such as degradation of the articular cartilage, thickening of the subchondral bone, formation of bony outgrowths (osteophytes), varying levels of inflammation in the synovial tissue, degeneration of ligaments and, the menisci, as well as hypertrophy of the joint capsule. Additionally, there may be other changes that could contribute to the development of OA or the symptoms associated with OA [11].

Comorbidities, which may result of a lack of physical exercise, drug toxicity, or the effects of inflammatory cytokines, are frequently linked to OA. According to estimates, 31% of people with OA also have at least five other illnesses. Due to lower levels of physical activity, individuals with hip and knee OA had a 20% increased risk of death when compared to controls of the same age [12]. Osteoarthritis is more likely to be observed along with 70 to 74-year-olds. This ratio reaches 40% in people with osteoarthritis. However, only 15% of these patients complain of pain [13,14].

2.1.1. Development and Progression of Knee Osteoarthritis

It is categorized under two headings: idiopathic and secondary. Secondary conditions may consist due to post-trauma, malformation, malposition, operations, metabolic diseases (rickets, hemochromatosis, chondrocalcinosis, ochronosis), endocrine disorders (acromegaly, hyperparathyroidism, hyperuricemia, etc.) [15].

Although there are many structures in the knee, hyaline joint cartilage is the starting point of OA. Cartilage provides comfortable sliding at the moment of joint movement and provides this with a smooth surface.Lubricin and hyaluronic acid, which

are produced by chondrocytes and synovial cells, are responsible for this smooth surface [16]. The first changes and deterioration in osteoarthritis occur where the mechanical forces and shear stresses are most significant, for instance, on the lubricated joint surface. These mechanical stresses stimulate the metabolic activity of the chondrocytes. The chondrocytes then try to compensate for the possible damage, but when these effects are excessive, it exceeds their ability to compensate, and matrix degradation occurs [17,18,19].

In an average adult, when the cartilage is at rest and not under stress, the chondrocytes work much more slowly, forming fewer cycles in the cartilage matrix. In osteoarthritis, chondrocytes are activated by increased matrix-degrading enzymes of matrix proteins. Disruption of the resting state can lead to remodeling of the matrix, inappropriate hypertrophy, and cartilage calcification [20].

On chondrocytes, the extracellular matrix (ECM) has receptors that react to mechanical stimulation. Proteinases that break down the extracellular matrix and cytokines and chemokines that encourage inflammation are produced when these receptors are stimulated [21].

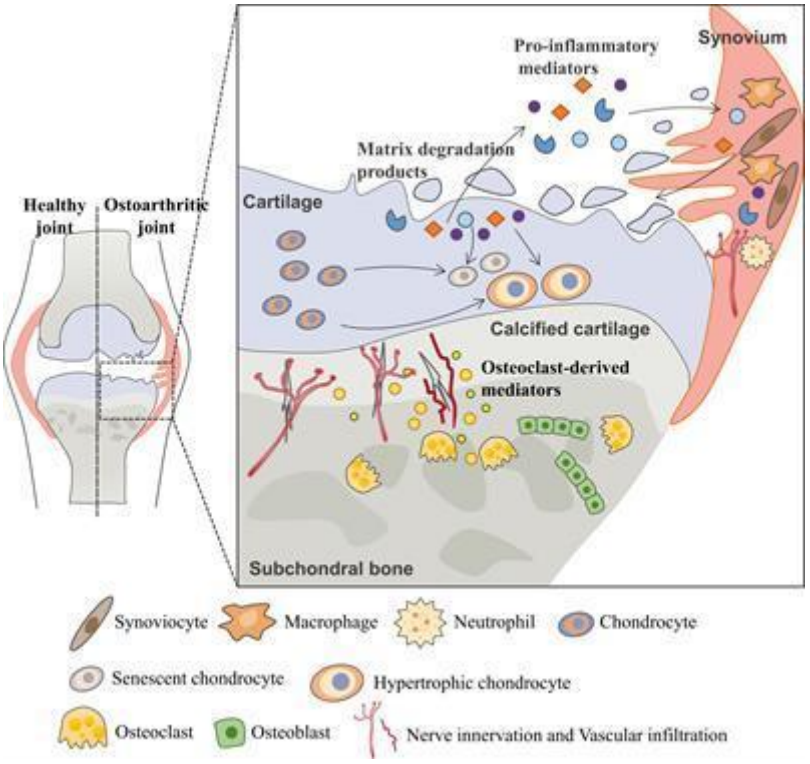


Figure 2.1. Pathophysiology of Osteoarthritis [22]

The purpose of inflammatory cytokines in encouraging the breakdown of cartilage through enzymatic mediators is to prevent post-traumatic osteoarthritis (PTOA). Common injuries that lead to PTOA include anterior cruciate ligament disruption, meniscus injury, and intra-articular fractures. These injuries cause hemarthrosis, chondrocyte death, and bone bruising, releasing inflammatory mediators during the acute post-injury period [23].

It is widely acknowledged that individuals with KO often experience pathological changes in their menisci and ligaments, with injuries to these structures being a common risk factor for developing OA. Even people without a known history of joint trauma may exhibit such changes, as seen in MRI studies [24]. A study conducted by D T Felson et al. aimed to investigate baseline MRI scans of knees that later developed OA within an 84-month follow-up period, and the researchers evaluated the severity of cartilage, meniscus, bone marrow, and synovitis lesions. The findings demonstrated that meniscal injury, synovitis, cartilage lesions, and bone marrow lesions were each risk variables causing OA in bivariate analysis. After multivariate analysis, however, only synovitis was identified to be substantially correlated with incident OA, and the probability of developing OA increased with a greater synovitis score.

In adults with symptomatic KO, about 63% experience meniscal damage [25]. A longitudinal study revealed that individuals with significant meniscal damage were 7.4 times more likely to develop radiographic knee OA after 30 months [26]. Furthermore, anterior cruciate ligament (ACL) injuries are frequently seen in elderly with KO.. ACL rupture was found in 22.8% of individuals with symptomatic knee OA, despite the fact that less than half of those with total ACL rupture had a history of trauma [27]. Gross morphologic alterations in the menisci have a high association with those in the patellar cartilage. The meniscus in the knee joints of people with osteoarthritis (OA) shows increased blood vessel growth and nerve densities that transmit sensory information. This observation suggests that the menisci may contribute to the pain experienced by individuals with knee OA [28].

Ligament degeneration is frequently observed in knee joints removed during joint replacement surgery, especially in the posterolateral side of the anterior cruciate ligament . Histologic changes in ligaments involves degeneration of matrix and collagen fibers. OA's Radiographic severity correlates with anterior cruciate ligament changes

but it is not related with PCL changes [29,30]. Local bone damage due to repetitive, excessive loading can also trigger bone remodeling, causing microcracks , as evidenced by MRI of individuals with OA. Skeletal adaptation can also take place near the borders of a joint, where endochondral ossification produces new bone. The cellular processes of bone growth are replicated by this process [31].

Excessive pressure on bones can lead to bone marrow lesions, which can be observed through magnetic resonance imaging (MRI). The biomechanical environment also affects the development of OA. Apart from ligament impairment, varus or valgus laxity could also contribute to KO. For instance, varus alignment is related with the medial side of the knee OA, while valgus alignment is related with the lateral compartment [32,33]. A study about knee alignment showed that valgus alignment was related with a borderline increase in the progression of KO. As well as increasing degree of varus alignment is related with development of KO. [34].

2.1.2. Assessment of Osteoarthritis

The diagnostic evaluation of osteoarthritis (OA) aims to confirm or exclude its presence in a patient. To achieve this goal, clinicians rely on four main elements: The patient's history, complaint, physical examination, and imagining studies. In some cases, blood tests may be necessary. People with OA experience pain and stiffness in the joint(s), which is often more pronounced at the beginning of the day or after staying still for a while (sitting, napping) and raises within half an hour. Clinicians should distinguish between symptoms of OA and other conditions that may lead to joint pain, which include infectious and crystalline (e.g., gout, pseudogout) arthritis, inflammatory (e.g., rheumatoid), infectious, and soft tissue lesions like bursitis, tendonitis, and meniscal tears. While the stiffness associated with inflammatory arthritis normally lasts longer than sixty minutes, the sensation of pain associated with crystalline arthritis is frequently acute. Retro patellar discomfort sufferers may have patellofemoral osteoarthritis (OA), which can occur on its own or in combination with tibiofemoral OA. Patellofemoral OA patients have severe pain when they climb stairs, get into and out of vehicles, or get in and out of baths because the patellofemoral joint gets stressed when the joint is flexion position [35,36].

Osteoarthritis has characteristic clinical symptoms, signs, and radiological changes that can be used to develop a staging system to track disease progression. The WOMAC osteoarthritis index is one such system that measures the severity of the disease by assessing pain and loss of function [37].

2.1.2.1. History

Patients with osteoarthritis commonly experience pain during movement, particularly when initiating or walking, frequently reported as a dull aching. Joint function is severely hampered as the condition worsens and the discomfort becomes persistent. One established risk factor for osteoarthritis is joint trauma, which accounts for 12% of instances of KO. Examples include an ankle fracture or anterior cruciate ligament rupture.. As the disease progresses, the pain becomes constant and significantly impairs joint function. Joint trauma, such as an anterior cruciate ligament rupture or ankle fracture, is a known risk factor for osteoarthritis and accounts for 12% of KO cases. Previous joint injury is an established risk factor for developing osteoarthritis, with about 12% of all cases attributed to such trauma [38].

2.1.2.2. Physical examination

Individuals with osteoarthritis typically have either no knee effusions or small, cool effusions on physical examination. Patients with effusions may exhibit Baker's cysts or swelling extensions that can be observed at the posterior side of the patella. Warm and easily palpable effusions in the knee are typical of inflammatory, infectious, or crystalline arthritis. Anserine bursitis and trochanteric bursitis are examples of soft tissue diseases which is extra-articular findings, and they do not result in joint effusions, they can be observed by localized aches and pains. Each stage of osteoarthritis has unique physical signs, with knee pain being the primary symptom that worsens during movement and improves with rest. Continuous pain at rest or during nighttime may indicate advanced osteoarthritis. During the physical examination, it's crucial to evaluate every related result, including those obtained from inspection, palpation, range of motion (ROM) testing, and various functional examinations such ligament stability tests, meniscus tests, Zohlen test, and gait analyses. Additionally, the femoropatellar joint should be examined for aches and pains and the menisci should be physically

evaluated for diagnosis [39]. In addition, bony enlargement and crepitus commonly occur in the joint [40].

2.1.2.3 Imaging

Magnetic resonance imaging (MRI) is a highly effective method for visualizing hyaline cartilage in the joints. In contrast, Ultrasonography is a method used to see soft tissues and areas filled with fluids, but it heavily depends on the examiner and requires significant expertise to interpret accurately [39]. Anteroposterior (AP) knee radiographs are used technique for radiographically assessing knee OA in clinical practice. The anatomic axis of the knee can be determined by measuring the femorotibial (FT) angle on AP radiographs. Except in cases where there is a suspicion of diseases like subchondral insufficiency, fracture, tumor, or infection that would require different and more urgent treatment than OA, MRI is rarely required in the assessment or therapy of knee or hip OA. MRI can identify abnormalities in cartilage, meniscus (in the knee), labrum (in the hip), bone, and synovium, among other joint components, giving a more complete picture of disease involvement [41].

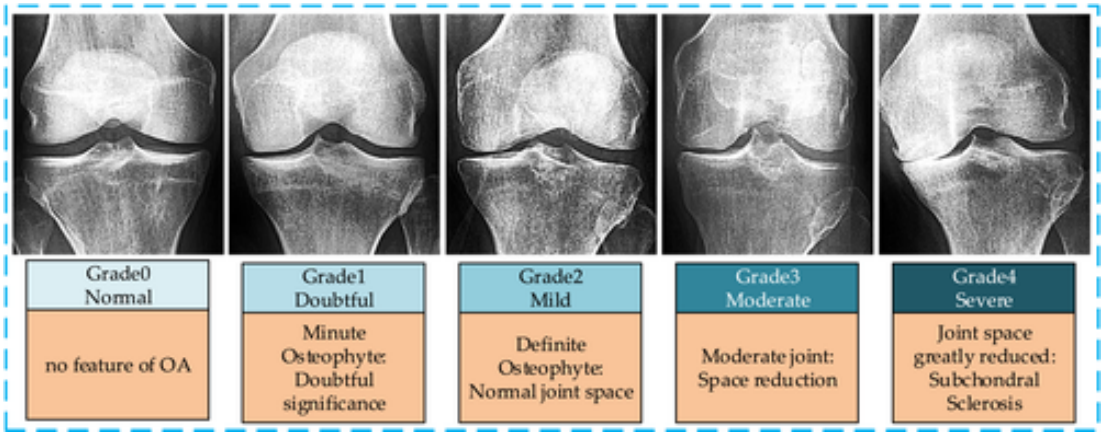


Figure 2.2. Kellgren-Lawrence Grading System [42]

The Kellgren-Lawrence grading system evaluates radiographic results. (Figure 2.2.). In the system, Grade 0 means representing no pathologic findings; Grade 1 questionable osteophytes; Grade 2 definite osteophytes; Grade 3 definite joint space narrowing; and Grade 4 progressive joint space narrowing [43].

2.1.3. Treatment Methods of Osteoarthritis

The management of osteoarthritis has been guided by many professional organizations. Guidelines recommend non-pharmacological interventions for OA patients, such as education, weight loss (for overweight individuals), and exercise. Structured exercise programs that target the lower extremity muscles have been shown to improve pain and functional status, with a standardized mean difference (SMD) of 0.52 for knee OA and 0.34 for hip OA [44,45,46]. A guideline for the treatment of KO has been published by the German Societies. The guideline outlines five principle of treatment: pain relief, improved quality of life, enhanced mobility, better walking ability, and delayed progression of osteoarthritis [47].

2.1.3.1. Physiotherapy Techniques

Physiotherapy for KO involves a combination of exercise therapy and physical interventions, which includes transverse friction(a manual therapy technique), electrotherapy, usage of heat and cold, and ultrasound (to reduce pain and promote endogenous healing processes), acupuncture, exercise, and traction [39].

A study by Deyle. et al. examined the effect of weekly massages for short-term treatment of KO. The results showed that weekly massage provided significant symptom relief and was safe for patients. This study also evaluates the effectiveness of manual physical therapy combined exercise for knee KO. The results showed weekly massage is an attractive short-term treatment option for KO, and a combination of manual physical therapy and supervised exercise contribute functional benefits.

A meta-analysis found that therapeutic ultrasound can effectively reduce pain and improve the WOMAC osteoarthritis index in KO patients. Additionally, therapeutic ultrasound can increase the active range of motion while reducing pain. Therefore, therapeutic ultrasound is a good option to reduce pain and change physical wellness in patients in positşve way with KO [48]. In addition to ultrasound, many researchers investigated the instant result of transcutaneous electrical nerve stimulation (TENS) on knee pain while performing activities in people with mild-to-moderate KO. TENS is a non-invasive pain management technique that uses low-voltage electrical currents applied to the skin to modulate pain perception for OA [49].

2.1.3.1.1. Transcutaneous electrical nerve stimulation (TENS)

TENS is frequently used by diverse healthcare practitioners to alleviate pain in clinical settings. Traditional TENS involves the application of high-frequency electrical stimulation characterized by low intensity and narrow pulsing frequencies exceeding 50 Hz combined with low intensity, it induces paresthesia while avoiding muscle contractions. Sensory-level TENS is applied, gradually increasing the voltage until it reaches a level that the patient can tolerate without discomfort or triggering any contractions. The primary objective is to selectively stimulate large-diameter, low-threshold non-noxious afferent nerve fibers (A-beta fibers). This method is particularly effective for managing pain that is distributed along dermatomes.

Motor level TENS is applied to elicit muscle contractions. Typically, the intensity gradually increases until it reaches a point before becoming noxious. A low frequency of less than 10 Hz is employed with high intensity. Intense TENS, often called a "counter-irritant," primarily targets small-diameter, high-threshold cutaneous afferent nerve fibers (A-delta fibers). The main objective of this type of TENS is to inhibit the transfer of nociceptive information while simultaneously activating other analgesic mechanisms. High frequencies and intensities are utilized for limited durations during intense TENS therapy.

Acupuncture-like TENS (AL-TENS) is an alternative approach that involves hyperstimulation and is commonly employed for patients who do not respond to conventional TENS. AL-TENS focuses on using low-frequency, higher intensity, and more extended pulse width for stimulation. The primary objective of AL-TENS is to activate small diameter, high threshold peripheral afferent nerve fibers (A-delta fibers).

The gate control theory is frequently used to describe how TENS inhibits pain. According to this theory, when TENS stimulates large-diameter afferent fibers, it hampers the transfer of nociceptive signals in the dorsal horn. The gate control theory suggests that segmental inhibition occurs through the involvement of neurons in the spinal cord's gelatinous substance. Spinalization, which eliminates descending influences that would otherwise inhibit the TENS unit, partially prevents the inhibitory effects of high-frequency TENS. However, even after spinalization, a significant amount of inhibition remains. Therefore, TENS appears to produce both segmental and

descending inhibition mechanisms [50,51,52,53].

In a study conducted by Lawson D. et al., twenty volunteers with knee OA classification of graded 2-3 were recruited to perform some specialized tests; 6-minute walk test (6-MWT), stair climb test (SCT), knee extensor strength test (KES), 2-step test from the locomotive syndrome risk test (LSR_2ST), and timed-up-and-go test (TUG). The study showed that knee pain during SCT, TUG, and LSR_2ST tests was significantly lower when subjects used the active TENS compared with using the inactive unit. However, there was no significant difference in pain level between the active and passive TENS during the 6-MWT and KES tests. In conclusion, the study suggests that TENS can provide analgesic effects to people with mild-to-moderate KO when applied along with functional activities.

While limited evidence supports thermal modalities such as cold and heat, patients with KOA have individual preferences regarding these treatments. Women tend to prefer heat therapy, while men favor cold or contrast therapies, though a response to these modalities varies.

2.1.3.1.2. Ultrasound

Ultrasound (US) is a viable rehabilitation technique that can alleviate pain and inflammation. It functions by generating mechanical energy through high-frequency vibrations, leading to the occurrence of acoustic streaming and radiation forces. These phenomena facilitate the movement of particles across cell membranes. As the sound wave transfers energy to the material, it induces vibration of the particles. Consequently, the heightened molecular movement within the tissue can lead to heat production, allowing US to produce thermal alteration in the tissues.

The US device comprises a high-frequency generator with a 1 or 3 MHz frequency. A quartz crystal changes its shape, specifically compression and relaxation by applying varying frequencies with an electrode. These alterations generate ultrasonic waves through the Piezoelectric effect. In thermal mode, US is most effective in heating dense collagenous tissues and necessitates relatively high intensity, preferably in continuous mode, to achieve the desired outcome. US is commonly employed to penetrate deep into

tissues and enhance collagen elasticity, particularly in the initial stages of a flexibility program. Pulsed US is generally recommended for addressing pain and inflammation in the early stages, whereas continuous US is more suitable for addressing movement-related issues.

The extent of US (US) absorption varies among different tissue types, indicating that certain tissues have a higher capacity for US absorption than others. Generally, tissues with larger protein density exhibit greater absorption of US, while tissues with low density absorb minimal US energy (e.g., blood and fat) [54,55,56,57,58,].

Many US machines provide the option for pulsed output, which clinicians often prefer. Historically, the pulse duration, was predominantly set at 2ms (2 thousandths of a second), with a variable off period. Some devices allow varying times, although the clinical significance of this feature is yet to be determined. Common pulse ratios include 1 to 1 and 1 to 4, although other options are available (refer to dose calculations). In the 1 to 1 mode, the machine delivers an output for 2ms, followed by a 2ms rest period. In the 1to 4 mode, the 2ms output is followed by an 8ms rest period [59].

The interaction of cavitation and acoustic streaming is principally responsible for the non-thermal effects of the US . Cavitation is the term used to describe the development of gas-filled cavities inside bodily tissues and fluids. It may be divided into two types: stable and unstable, each with a different set of consequences. Stable cavitation occurs at therapeutic doses of US and involves the formation and growth of gas bubbles through the accumulation of dissolved gas in the medium. On the other hand, unstable (transient) cavitation occurs when bubbles form during the low-pressure phase of the US cycle and rapidly collapse, releasing a significant amount of energy that can be detrimental to tissue viability.

On the other hand, acoustic streaming describes the small-scale eddying of fluids near a vibrating structure, such as cell membranes or the surface of stable cavitation gas bubbles. This phenomenon influences diffusion rates and membrane permeability. It alters the permeability of sodium ions, resulting in alteration in the cell membrane potential. It also modifies the transport of calcium ions, thereby impacting the enzyme control mechanisms of various metabolic processes, particularly protein synthesis and

cellular secretions. The combined effects of stable cavitation and acoustic streaming lead to the "excitation" or upregulation of the cell membrane, increasing the overall activity levels of the cell [60,61].

The mode of action described above does not aim to increase the inflammatory response itself directly. Instead, it acts as an "inflammatory optimizer." The inflammatory response plays a crucial role in tissue repair, and the goal is to enhance the efficiency of this process rather than intensify it. Applying excessive US intensity at this stage could potentially lead to increased inflammatory response, although it is not the desired outcome.

During the proliferative phase involving scar production, US also stimulates cellular activity by regulating cellular activity. However, the primary targets during this phase shift to fibroblasts, endothelial cells, and myofibroblasts, which are actively involved in scar production. US acts in a proliferative manner due to its pro-inflammatory effect. It does not alter the ordinary course of the proliferative phase but maximizes its performance, facilitating the production of tissue optimally [62,63]. Studies, such as the one conducted by Harvey et al., have shown that low-dose pulsed US can increase protein production, and multiple other studies have shown enhanced fibroplasia and collagen production [64].

2.1.3.2. The Use of Orthopedic aids and Orthoses

In some cases, orthopedic aids or orthoses may be necessary to reduce mechanical stress on a joint. These aids can include cushioned heels and wedges that elevate the shoe's inner or outer side correct the axis, and provide shock absorption. Initially, some patients may resist using these aids, but they can become more receptive with proper education and support from orthopedic technicians and shoemakers.

A Cochrane Review assessed five controlled trials and found that patients who wore orthosis experienced less pain and better joint function than those who did not use these aids (with evidence level Ib) [65].

The use of assistive devices such as canes, walkers or crutches is recommended as a preventive measure. The cane should be held in the opposite hand, while the elbow is bent at an angle of 25-30 degrees, the height of the cane should be adjusted to the level of the greater trochanter. (IIaB) [66].

2.1.3.3. Pharmacotherapy

OA is commonly treated with non-steroidal anti-inflammatory drugs (NSAIDs) as a primary pharmacologic intervention. Multiple placebo-controlled studies have demonstrated that NSAIDs provide more significant pain relief than placebo [67]. When inflammation symptoms appear, intra-articular glucocorticoid injections can quickly reduce joint effusion. In a study (Evidence level Ia) it was shown that intra-articular corticosteroid injections considerably reduced pain two weeks and three weeks after the injection when compared to placebo, hyaluronic acid, and lavage. The current guidelines of the American Academy of Orthopaedic Surgeons (AAOS) suggests these injections should only be used for short-term treatment of osteoarthritis). Septic arthritis is a significant possible complication associated with these injections. A research from Iceland found that the risk of septic arthritis was 0.037% per corticosteroid injection. As a result, an incident of joint infection problems following intra-articular corticosteroid injection occurs per 2633 injections in Iceland [68,69,70].

Individuals who have bleeding peptic ulcers in their history are usually not recommended NSAIDs due to the possibility of gastrointestinal bleeding [67]. For patients who cannot take NSAIDs or do not respond to them, intra-articular corticosteroid injections can be an alternative. These injections usually provide pain relief for a few weeks and are particularly useful for OA affecting a single joint that is easy to inject, like the knee. While corticosteroid injections are not superior to placebo for pain relief after three months, they may be less effective than physical therapy at one year [71]. Since mechanisms in the central nervous system may cause OA pain, several medications, including a serotonin-norepinephrine reuptake inhibitor, have been used to address pain of central origin. Randomized trials have demonstrated that this medication provides analgesic effect than a placebo in people with KO [72,73].

2.1.3.4. Surgery

The recommendation for surgery in cases of advanced osteoarthritis is to consider it only after non-surgical options have been exhausted and when the patient experiences severe subjective impairment due to their symptoms. Intra-articular surgeries are mostly conducted using an arthroscope, which offers benefits such as minimizing possible trauma. [74].

Arthroscopic lavage, first described by Burmann in 1934, is a technique used to remove debris and inflammatory mediators from the joint [75]. Shaving, also known as chondroplasty, involves removing damaged cartilage that is frayed or fragmented and smoothing the edges. However, studies have shown that chondroplasty only provides short-term benefits and does not have a long-term impact. Chondroplasty is typically performed in cases where the cartilage damage is classified as Outerbridge stages 2 or 3 [76].

Debridement is a technique first described in 1941 by Magnuson, which involves removing debris and diseased tissue from the joint. Debridement has the same goal as arthroscopic lavage and chondroplasty to relieve joint pain and inflammation. It is effective way for treating meniscal disruption, removing free-floating bodies, and relief the symptoms of osteophytes [77].

Corrective osteotomy is a surgical procedure that can be performed near the knee joint. It is typically performed on either the distal side of the femur or the proximal side of the tibia. This procedure aims to shift the joint's weight-bearing axis away from the affected area, which is subjected to excessive mechanical stress. By doing so, the joint is tipped out of this high-stress zone and redirected towards the still intact portion [78].

2.2. Somatic Nervous System

A part of the peripheral nervous system known as the somatic nervous system is involved in the voluntary adjustment of skeletal muscle movement. It is in charge of each of the physical motions we are aware of and have conscious control over, such as that of our arms, legs, and other body parts. In order to carry out our daily activities, the somatic nervous system integrates the central nervous system with many organs and striated muscles [79].

2.2.1. Central Nervous System

The central nervous system (CNS), including the brain and spinal cord, communicates with the neuromuscular junction (NMJ) using electrical impulses converted to chemical signals for muscle contraction. Sensory receptors in the periphery detect information and send it to the CNS as electrical signals.

The primary motor cortex in the precentral gyrus contains upper motor neurons that initiate the fundamental motor pathway.These neurons communicate with the lower motor neurons through axons in the spinal cord with the corticospinal tract. The lower motor neurons are then connected to the signals of the ventral horn neurons of the spinal cord. The lower motor neurons send signals through peripheral axons to the skeletal muscles' neuromotor junction (NMJ).
The upper motor neurons release a neurotransmitter that creating a stimulus that propagates towards the NMJ, which innervates muscles and triggers muscle contraction [79].

2.2.2. Somatosensory System

It is a component of the sensory system, which has receptors in the skin, fascia, joints, muscles, and ligaments among other regions of the body. These receptors are responsible for detecting environmental changes. These are exteroceptive receptors and changes within the body, referred to as proprioceptive receptors.

The somatosensory system transmits sensations from the periphery to the sensory cortex in the parietal lobe. It involves three neurons that work together, with the first-order neuron residing in the dorsal root ganglia and transmitting the sensory impulses through the spinal cord to the second-order neuron placed in specific areas depending on the type of sensation. The axons of the first-order neuron travel either ipsilaterally or contralaterally, and the cell bodies of the second-order neurons are located in distinct anatomical regions based on the type of sensation they convey. The sensory afferents carry the impulses from the periphery, and the pathways involve the spinal cord, brainstem, and thalamic relay nuclei.

The ganglion at the dorsal root contains the cell bodies of the peripheral afferent fibers and any sensations are detected, they are transferred through the to the dorsal root ganglion. where the first-order neurons are placed. Bundles of neurons from the dorsal root ganglion and their central processes travel to enter the spinal cord. They divide into two functional groups: the lateral group, also known as the anterolateral system, and the medial group, or dorsal column-medial lemniscal system. Both systems mediate the sensation of touch.

The lateral group comprises generally unmyelinated fibers. These fibers which do not have myelin sheath, carry pain and temperature information. Once the fibers of the lateral group enter the spinal cord, they travel up or down around two segments of the spinal cord (within the tract of Lissauer) to reach their destination in the substantia gelatinosa and the nucleus proprius. This is the place that second-order neurons reside. These neurons contain projections that go through the anterior white commissure to the opposing side (decussate). The spinothalamic tracts (STT) allow the fibers to rise from the brainstem to the thalamus.

The medial group consists of fibers that have myelin sheath that transmit proprioceptive information. Although most of these fibers rise to the dorsal column nuclei in the medulla, where they synapse, they also penetrate the posterior spinal cord. The gracile and cuneate tracts are two distinct components of the ascending tracts, together known as the posterior funiculus. Fibers that begin below the sixth thoracic segment are carried via the gracile tract. In contrast, the cuneate tract has fibers above the sixth thoracic segment and is located more laterally in the spinal cord.

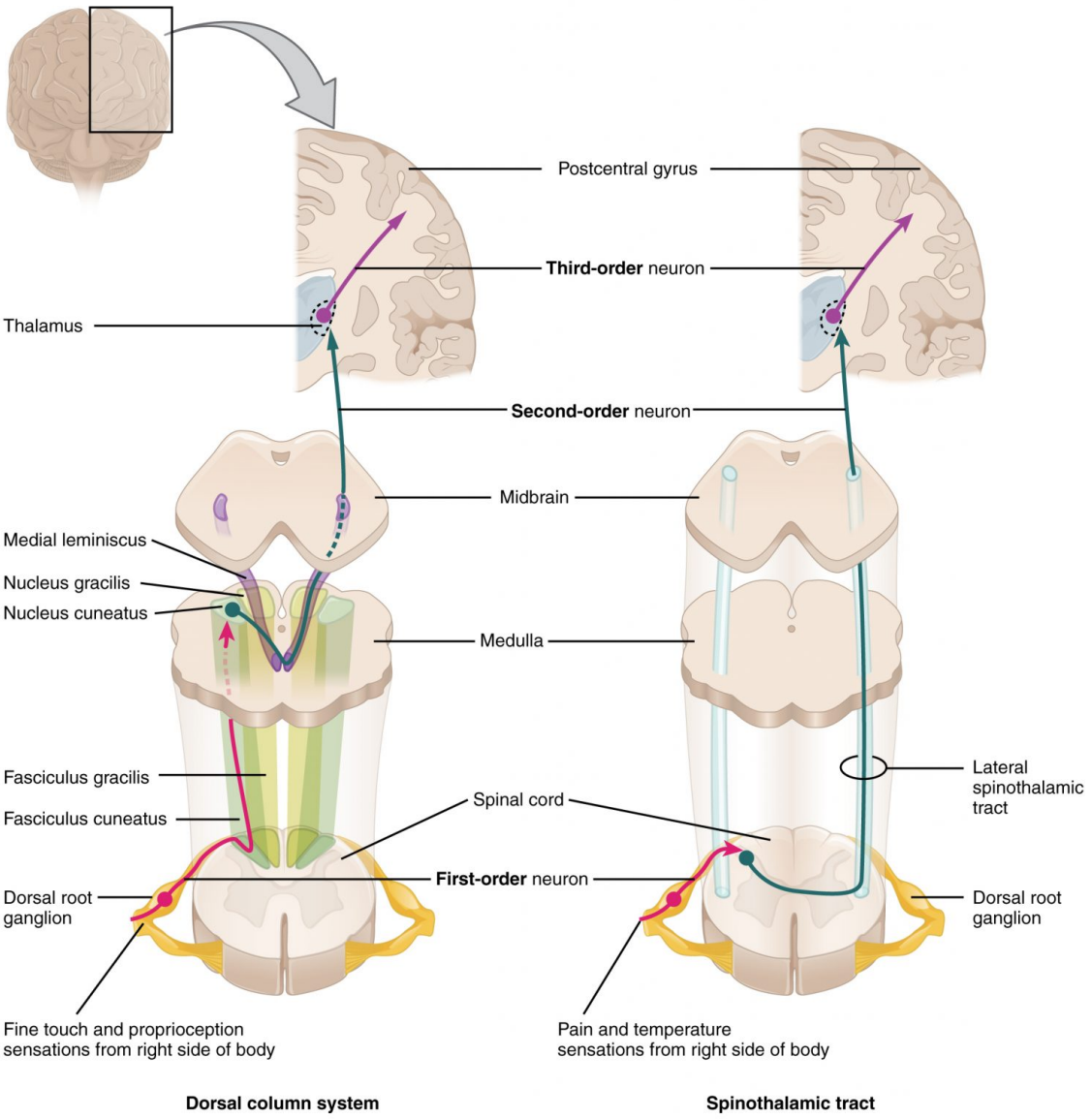


Figure 2.3. Somatosensory Pathway [81]

The second-order neurons in the nucleus gracilis and cuneatus receive input from these tracts. Then their axons cross over (via internal arcuate fibers) to form a bundle known as the medial lemniscus, also called sensory or lemniscal decussation. The gracile and cuneate nuclei in the medulla are ventral to the medial lemniscus. Position sensing and fine discriminative touch are the main functions of the posterior columns and medial lemniscus fibers.

The third-order neurons begins from the thalamus and reaches to the primary somatosensory cortex through the posterior limb of the internal capsule. The primary somatosensory cortex is located in the postcentral gyrus of the parietal lobe, including Brodmann areas 1, 2, and 3, as well as the posterior paracentral lobule. This area

processes general and proprioceptive sensations, integrates sensory information, and is organized into a sensory homunculus. The homunculus has a disproportionate representation of particular body parts, with those critical to the sensory system having a larger model, such as the face, lips, and hand [80,81,82,83].

2.2.2.1. Testing Dorsal Column Function

Testing vibration sense is the best effective clinical assessment of the dorsal column pathway. To conduct this test, a low-frequency diapason, with 128 Hz, is applied to prominent bony areas while the patient is instructed to indicate the onset and cessation of vibration with closed eyes. While evaluating light touch and proprioception is possible, these measures are comparatively less reliable. A delicate application of cotton wool onto different skin regions can be tested for assessing light touch. In evaluating proprioception, the patient is asked to discern whether the examiner is flexing or extending various joints, once again, with closed eyes. Additionally, impaired joint position sense can manifest as difficulty maintaining an upright stance with closed eyes, commonly known as Romberg's sign [84].

2.2.2.2. Receptors of the Sensory System

They are specialized structures that respond to alterations in the area around them. These receptors can be classified based on their ability to adapt to a stimulus, which refers to their capacity to decrease their discharge rate with continuous or repetitive stimulation.

Some receptors can adapt, meaning they respond strongly to a stimulus when first applied, but the response will decrease as the stimulus continues. These are known as quickly adapting receptors or phasic receptors. In contrast, non-adapting receptors, also called tonic receptors, will continue to discharge at a constant rate for the duration of the stimulus.

There are three distinct categories of sensory receptors, distinguished by the location of the stimulus they perceive. The first type, known as exteroceptive receptors or exteroceptors, responds to alterations in the surroundings The second type, proprioceptive receptors or proprioceptors, collect knowledge about the body's locations in space. The third type, interoceptive receptors or defines as interoceptors, identify information of organs. Additionally, depending on the stimulus they detect, sensory

receptors are categorized as mechanoreceptors, thermoreceptors, or nociceptors. These receptors can be classified as 3 different endings.

Free nerve endings are composed of delicate, do not have myelin sheath, nerve fiber branches distributed throughout the skin, subcutaneous tissue, and organs. These receptors are nonadapting and specialize in detecting pain and temperature sensations.
On the other hand, fluid-filled nerve terminals are surrounded by layers of concentric tissue in encapsulated nerve ends. These receptors are highly sensitive and adapt quickly to changes in stimuli. They are responsible for transmitting information related to vibration, delicate discriminative touch, and deep touch. Subcutaneous tissue, palms, fingers, lips, skin, and external genitalia all have encapsulated nerve terminals.

Expanded tip endings are nerve endings that have a bulbous expansion or knob that serves as a receptor at the distal end of the neuron. These receptors are in charge of sensing temperature, pressure, and touch as well as visceral information with examples including Merkel receptors and Ruffini endings. These receptors exhibit moderate adaptation rates and slower conduction speeds and can be found in the dermis and joints. On the other hand, mechanoreceptors are specialized sensory receptors that detect the mechanical displacement of nerve endings, mediating a range of sensations, including, pressure, vibration, touch, limb position (proprioception), and limb movement (kinesthesia). These receptors are typically characterized by large-diameter, myelinated fibers allowing fast impulse transmission.
Nociceptors are a type of sensory receptor that functions as high-threshold mechanoreceptors, characterized by their ability to detect noxious stimuli, including heavy mechanical stimulations, excessive temperatures, and other potentially harmful stimuli that may result in tissue damage. These receptors are primarily composed of free nerve endings and often act as specialized chemoreceptors, detecting a variety of substances. Nociceptors are primarily associated with slowly progressing, lightly myelinated A-delta fibers, which convey cutaneous pricking pain.

Unmyelinated C fibers convey poorly localized and poorly tolerated secondary pain, often characterized by a burning sensation and can persist over long periods. These fibers conduct impulses relatively slowly, at approximately 1 m/sec. Unmyelinated C fibers and myelinated A-delta fibers within the sympathetic nerves convey deep pain originating from the viscera, muscles, and joints, often associated with referred pain.

Thermoreceptors, on the other hand, are specialized sensory receptors that detect changes in temperature and mediate the sensations of cold and heat. Relatively few changes in temperature trigger these receptors. High temperature thermoreceptors are composed of C fibers, while A delta fibers mediate the perception of low temperature.

Muscle spindles and Golgi tendon organs are two significant receptors involved in the mediating of position sense. Skeletal muscles include enclosed structures called muscle spindles that measure muscle length and rate of length change. A capsule of connective tissue surrounds each spindle up to a dozen thin muscle fibers. Tiny nuclear chain fibers, which have a single chain of central nuclei, and big nuclear bag fibers, which have several tiny nuclei in the central area, are the two different kinds of intrafusal fibers. Tactile discs of Merkel are also involved in position sense and are located between dermal papillae. They comprise a neurofibrillary disk closely contacting a single modified epithelial cell.

The sensory innervation of muscles involves primary and secondary afferent nerve fibers. The primary afferents, which originate from Ia nerve fibers, surround the main zones of both chain and bag fibers. The secondary afferents, on the other hand, are mainly derived from type II nerve fibers. These afferent nerve fibers synapse on alpha motoneurons at the spinal cord level and modulate their activity. Their role is controlling both the stretch reflex and tone of the muscle. The mainly endings are responsive to physical changes in muscle and can measure the velocity of stretch, while the secondary endings mainly assess the extension of the muscle.

Intrafusal muscle fibers have gamma and beta motor neurons that stimulate the contractile end. Gamma motor neurons cause intrafusal muscle fibers to contract, increasing the responsiveness of sensory afferents and resetting the spindle mechanism. The encapsulated Golgi neurotendinous organs are located at the point where the muscle and tendon intersect. They also have their capsule and an afferent Ib nerve fiber. Stretching the tendon stimulates Ib afferents. By polysynaptically projecting onto them at the spinal cord level, these fibers block alpha motor neurons that innervate agonist muscle groups and support motor neurons of antagonist muscle groups [80,81,82,83].

3. MATERIAL AND METHODS

3.1 Subjects

A single-center, prospective, experimental, parallel-group, randomized controlled study was carried out by participants with KO. The study group consisted of aged between 65-85 who had KO and met the inclusion criteria(n=25). After filling out the evaluation form document, including demographic and clinical characteristics from all participants at their first visit, the Western Ontario and McMaster Universities Arthritis Index(WOMAC) and Physical Activity Scale for the Elderly (PASE) are filled out. Then participants were separated randomly as a control group (CG) (n=13, Age Means±SD= 77.23±7.46) and thera-train Cycle Ergometer group (CEG) (n=12 Age Means±SD= 74.75±7.6).

The study protocol was approved by Yeditepe University Ethical Committee (protocol number: E.83321821-805.02.03-51). The clinical registration number is 202207Y0269. The aim and plan of the study were explained, and informed written consent was obtained from each patient. We analyzed the power using G * Power version 3.1.9.7 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf Germany) software. Based on a preliminary analysis of differences between two independent instruments in sample size were calculated. A total of 22 cases for an initial investigation was determined with a power independent of 0.9 and an alpha (α) error of 0.10.

3.1.1 Inclusion Criteria

The inclusion criteria of the study were being between 65-85 years of age, knee osteoarthritis Kellgen-Lawrance stage between 1-3, and voluntary participation in the study.

3.1.2. Exclusion Criteria

The exclusion criteria of the study were previous knee surgery, systemic rheumatic diseases (Rheumatoid Arthritis, Ankylosing Spondylitis, etc.), diabetes mellitus, thyroid disease, visual deficit, gait disorder, mental disability, and presence of neuropathy.

3.1.3. Flow Chart of the Study Process

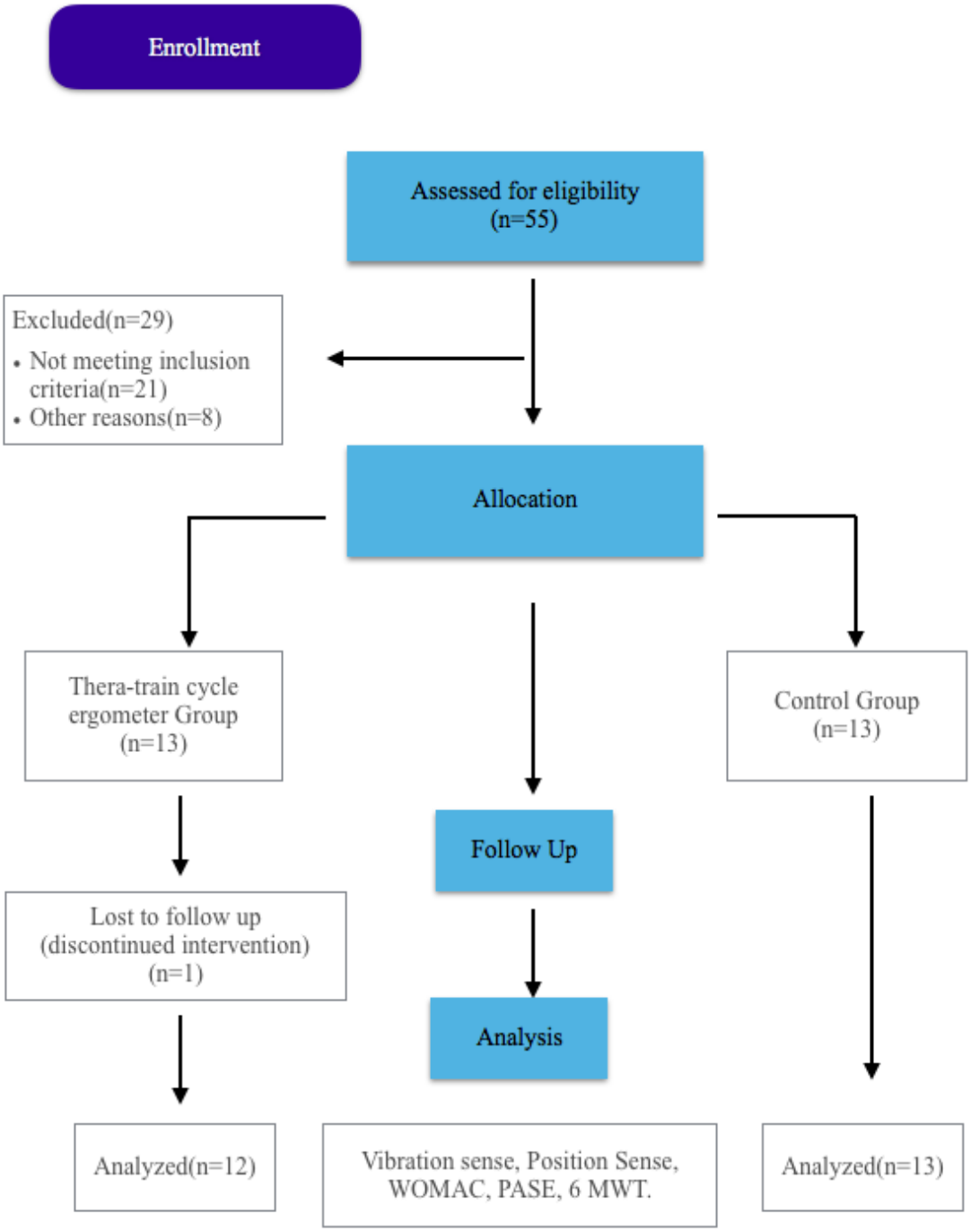


Table 3.1 Flow Chart

3.1.4 Study protocol

Participants among Sante Medical Center patients were recruited for the study between September 2022 and May 2023. The patients who declared their knee pain were assessed (n=55). After eliminating the unsuitable patients, we conducted the study with 25 people. (Table 3.1). Participants informed about the study and who volunteered to join the study were asked to fill in the attached documents, including demographic, clinical information, WOMAC, and PASE. Then vibration sense test, joint position sense test, and 6-minute walking test were applied. TENS, US, and isometric exercises were planned for all the patients as a treatment. In addition to the treatment, the Cycle Ergometer Group (CEG) performed pedaling on Thera-train Biofeedback Cycle Ergometer.

3.2. Assessment Methods

3.2.1. Demographic Information Questionnaire

This questionnaire was prepared to evaluate the demographic characteristics of the participants. It includes questions about the participant's demographic characteristics, socio-demographic status, previous disease, traumas, deficits and surgical operations, medications, exercise status, and smoking/alcohol habits. (Appendix C)

3.2.5 Diapason

Standard diapason (128 hz frequency) was used in the measurement of by vibration method. Knee positioned the 180 degree extension. After vibrating the diapason, it placed at the midpoint of the patella and the chronometer was started. When the patient did not feel the vibration sense they said that it was over and the chronometer stopped. It was noted how long they felt the vibration sense. Measurements repeated three times. Before each repetition, it ensured that there was no residual vibration in the diapason.

3.2.6 Digital Goniometer

The most common tool used to measure a range of motion (ROM) is the universal goniometer. Many studies show that technological goniometers are more reliable. A technological goniometer positioned on the lateral side of the femur between the greater

trochanter and the center of the lateral joint space of the knee, followed by the center of the lateral joint space of the knee and the lateral ankles, in order to measure the range of motion (ROM) of the knee joint (Rheault et al., 1988). The angular changes between the two locations, as determined by the goniometer, shows the range of motion (ROM) of the knee joint [85].

In the research, we evaluated joint position sense. The patient sat down and asked to swing their legs freely. When the patient stopped and relaxed, we positioned the single leg to 30 degree extension from the 90 degree knee flexion position for 5 seconds.

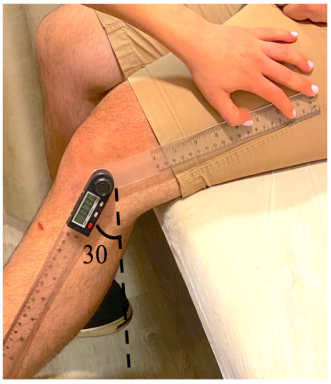


Figure 3.1. Measurement of Knee Position Sense with Digital Goniometer

Then we asked him or her to relax and do the same position again thrice without our guidance. We measured the knee joint angle with a digital goniometer every time. We repeated the same steps for the other leg. After that, we performed the same procedure for 60 and 90 degree extension.

3.2.4 6-Minute Walking Test (6MWT)

6MWT is a sub-maximal exercise test to evaluate endurance and aerobic capacity. It involves measuring the distance an individual covers for 6 minutes, which serves as an indicator to monitor changes in performance capacity. The results obtained from the 6MWT can provide valuable insights into the extent of functional impairment, particularly in cardiovascular and pulmonary conditions. These findings could guide therapy adjustments to address these conditions effectively. (Appendix D)

The popularity of the 6MWT stems from its simplicity and reproducibility, as it offers a comprehensive overview of the combined cardiovascular, pulmonary, and musculoskeletal response to exercise. During the test, participants can set their speed while walking as far as possible within a flat corridor. Standardized instructions and encouragement are provided to ensure consistency across tests. The final distance covered by the individual within the 6-minute timeframe is measured and recorded in meters [86].

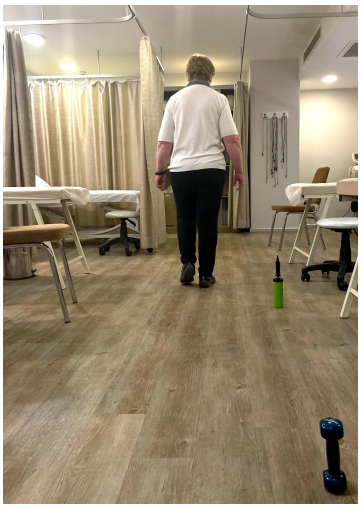


Figure 3.2. 6MWT

In addition to its applications in assessing endurance and aerobic capacity, the 6MWT has further utility in preoperative risk stratification [87].

The 6MWT is recommended by guidelines for testing endurance to exercise and determining predictions based on medical histories. The 6MWT can be used to evaluate requirements impacting any of these organ systems due to exercise influence several organ systems [88]. The 6MWT can be used to accurately determine conditions that affect the neurological or muscular systems, including spinal muscular atrophy, multiple sclerosis, fibromyalgia, and Parkinson's disease. Additionally, the 6MWT has demonstrated a substantial predictive value in determining ambulatory capacity following total knee arthroplasty [89,90,91].

The 6-Minute Walk Test (6MWT) has an established absolute contraindication: for those who have past acute coronary syndrome within the 1 month preceding the test. Individuals who have experienced these cardiac events within the specified timeframe should not undergo the 6MWT. There are also relative contraindications to the 6MWT, which indicate caution should be exercised when performing the test. These include

severe and uncontrolled hypertension (high blood pressure) . For example, while resting, the heart rate exceeds 120 beats per minute. In such cases, it is essential to consider the individual's overall health condition and consult with a healthcare professional to assess the appropriateness and safety of conducting the 6MWT [91]. Kennedy et al., in their study in 2005, stated that this test is reliable for OA. Excellent test-retest reliability (ICC = 0.94) [92].

3.2.3 Physical Activity Scale for the Elderly (PASE)

PASE was created in the early 1990s to address the specific need for an age-specific physical activity questionnaire, which was lacking in epidemiological research at that time [93]. It was designed to provide a tool for investigating the physical activity levels of older individuals.

The PASE questionnaire is divided into three main sections: leisure time activities, household, and work-related activities. This segmentation allows for a detailed evaluation of an individual's physical activities within each category. Additionally, it facilitates comparisons of these subheadings with other functional measures, such as physical performance assessments. Overall, the PASE questionnaire offers a comprehensive means of assessing and comparing the physical activity levels of older adults [94]. (Appendix E)

3.2.2. The Western Ontario and McMaster Universities Arthritis Index (WOMAC)

WOMAC is a widely utilized tool designed to assess symptoms and physical disability in individuals with coxarthrosis and/or KO. Initially developed to measure meaningful changes in health status resulting from treatment interventions, this index comprises 24 items distributed across three subscales: pain (consisting of 5 items), stiffness (2 items), and physical function (17 items). Within these items, participants indicate the extent of the difficulty experienced, such as the pain level while ascending or descending stairs or the challenges encountered when rising from a chair. The Likert version of the WOMAC uses a scale ranging from 0 to 4, with higher scores indicating higher levels of symptoms or physical disability. Each subscale, namely pain, stiffness, and physical function, has a maximum score of 20, 8, and 68, respectively. In addition to the subscale scores, an index or global score is commonly obtained by summing the scores from all three subscales. (Appendix F)

The WOMAC demonstrates convergent construct validity, as it exhibits meaningful correlations with various impairment measures such as range of motion and radiology Kellgren rating, as well as disability measures including Short Form-36 physical function and Nottingham Health Profile function scale. These correlations are moderate to strong, indicating a significant relationship between the WOMAC and these other measures.

In an initial validation study conducted as part of drug intervention research, both versions of the WOMAC (Likert and VAS) were administered to individuals with hip or KO. The test-retest reliability of the Likert version subscales for pain, stiffness, and physical function was measured to be 0.68, 0.48, and 0.68, respectively, using Kendall's tau c as a statistical measure. The VAS version's corresponding values were 0.64, 0.61, and 0.72 for pain, stiffness, and physical function, respectively. Regarding the global score, the Likert version had a test-retest reliability of 0.68 (Kendall's tau c), while the VAS version had a test-retest reliability of 0.64 (Kendall's tau c) [95,96].

4. INTERVENTION

4.1 Thera-Trainer tigo®

Cycle Ergometer allows individuals to carry out cyclical movements of the lower extremities from a chair. Patients sat in a chair with back support. The distance of the chair was adjusted so that the patient could cycle comfortably. After participants started cycling, two parallel bars appeared on the screen. We said that the bars on the screen should be close to 50 percent and the number of pedaling per minute should not exceed 45 which is seen on the top right on the monitor. These parallel bars show the rate of loads of both feet. The first 5 minutes are warming with 5 watts, 10 minutes for exercise with 10 watts, and the last 5 minutes are cooling down with 5 watts.

Figure 4.1. Cycle Ergometer With Biofeedback (Thera-Train Tigo)

4.2 Exercise

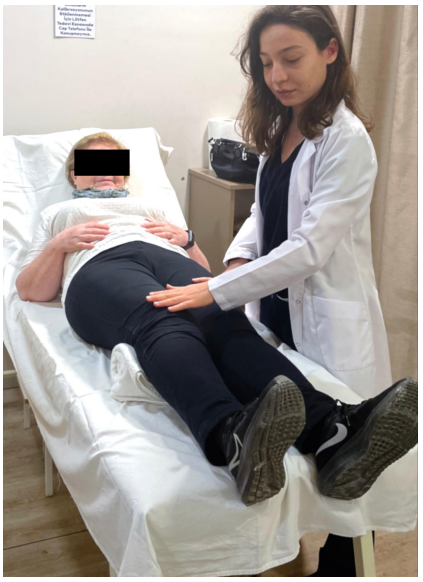
Isometric exercises consist of single-leg rising(supine position), standing with single-leg raised, and quadriceps isometric with the rolled towel. Each exercise was applied to the other leg after the sets.

Single-leg rising exercises were used on the bed with a mat. The patient laid down supine, and we asked to raise one leg approximately 45 degrees for 5 seconds. Then the patient relaxed for 5 seconds. The movement was done for two sets and ten

repetitions per set.Quadriceps isometric exercises were shown with the rolled towel. The towel was placed under the knee while the patient was lying supine. Then we asked the patient's toes to point upward and put pressure with the back of the knee directed at the towel. The position was maintained for 5 seconds and then relaxed. This activity was repeated ten times for two sets. Standing with single raised exercises was done while the patient was holding something. The Patients were standing upright, and we asked them to raise one leg as much as possible for 5 seconds. Each movement was done for two sets and ten repetitions per set.

a)

b)



c)

Figure 4.2. a) Single leg rising b)quadriceps isometric exercise c) Single leg rising with standing position

4.3. TENS

Tens was applied to the knees of the patients with 4 electrodes. The patients lay in the supine position and their knees were kept in extension. Tens was performed as modulated tens for 20 minutes.

4.4. Ultrasound

The patients lay in the supine position with their knees extended. Pulsed US was applied to the osteoarthritic knee for 5 minutes.

5. RESULTS

In this study, we have 25 participants diagnosed with KO. The participants were separated into Control and Cycle Ergometer Groups. Vibration sense, knee position sense (30, 60, 90 degrees), 6MWT, PASE, and WOMAC values have been assessed and analyzed before and after the 15-session intervention; changes in the groups and comparisons between the groups have been studied in the results.

Data Analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 29.0 software (SPSS Inc. Chicago, IL, USA). Chi-square test was used to evaluate gender distribution. Mann-Whitney U test test was used to evaluate the data before the intervention to determine the differences between the two groups. Wilcoxon signed-rank test has been used to evaluate group changes pre and post intervention. Mann-Whitney U test test was used to compare the data after the intervention to determine if the data of the study group had changed statistically differently compared to the control group. Statistically significance of the p-value was set as <0.05.

The gender distribution data of the participants is expressed as number and percentage in Table 5.1. There was no statistically significant difference between the groups.

Table 5.1. Comparison of Gender Distribution between Groups

	Cycle Ergometer		Control		p value	λ^2
Gender	n	%	n	%		
Male	1	8.3	1	7.7		
Female	11	91.7	12	92.3	0.953	0.003
Total	12	100	13	100		

Chi-square test

Demographic information has been analyzed, and there were no statistically significant differences between groups. Demographic information at the beginning of the study has been shown as mean and minus plus standard deviation in Table 5.2.

Table 5.2. Comparison of Demographics between groups

	Cycle Ergometer	Control	
Variables	Mean±SD	Mean±SD	p value
Age(Years)	74.75±7.6	77.23±7.46	0.352
Weight(kg)	78.91±13.66	74.61±8.45	0.462
Height(m)	161.66±6.12	161.00±8.74	0.566
BMI(kg/m²)	30.14±4.61	28.966±4.204	0.644

Mann-Whitney U test, SD: Standard Deviation, BMI: Body Mass Index, kg: kilogram, m: meter, kg/m²: kilograms/meter square

Demographics information, Deep sensation Assessments and Physical Activity Condition tests baseline results as mean and minus plus standard deviation have been shown in Table 5.3. Mann-Whitney U test was used to evaluate the difference between groups. Initially, there were no statistically significant differences between groups for all parameters.($p>0.05$)

Table 5.3 Comparison of Demographics, Deep Sensation Assessment, and Physical Activity Condition in between groups before the intervention

	Cycle Ergometer	Control		
Variables	Mean±SD	Mean±SD	z value	p value
Age(Years)	74.75±7.6	77.23±7.46	-0.930	0.352
Weight(kg)	78.91±13.66	74.61±8.45	-0.574	0.462
Height(m)	161.66±6.12	161.00±8.74	-0.736	0.566

BMI(kg/m²)	30.14±4.61	28.966±4.204	-0.462	0.644
Diapason(sec)	3.79±2.94	5.28±3.16	-1.226	0.220
30 degrees	9.66±5.07	9.53±5.19	-0.27	0.978
60 degrees	5.33±2.42	5.15±3.81	-0.191	0.849
90 degrees	2.16±2.39	4.23±7.93	-0.630	0.529
6MWT(m)	216.08±66.98	220.03±91.64	-0.654	0.513
PASE	38.91±27.10	32.61±32.24	-0.520	0.603
WOMAC	43.91±13.07	41.34±13.34	-0.463	0.644

Mann-Whitney U test, SD: Standard Deviation, sec; second, m; meter

Deep Sensation and Physical Activity Condition tests of Cycle Ergometer Group pre and post intervention have shown as mean and minus plus standard deviation in Table 5.4. There were statistically significant changes in all parameters ($p<0.05$).

Table 5.4 Deep Sensation Assessment and Physical Activity Condition tests of the Cycle Ergometer Group at baseline and after the intervention

	Baseline	After		
Variables	Mean±SD	Mean±SD	z	p-value
Diapason(sec)	3.79±2.94	6.73±2.03	-3.05	**0.00**
30 degrees	9.66±5.07	3.38±3.65	-3.05	**0.00**
60 degrees	5.33±2.42	1.66±1.24	-3.06	**0.00**
90 degrees	2.16±2.39	0.84±1.26	-2.09	**0.03**
6MWT(m)	216.08±66.98	276.16±53.92	-3.059	**0.00**
PASE	38.91±27.10	60.50±35.76	-2.93	**0.00**
WOMAC	43.91±13.07	16.57±12.99	-3.06	**0.00**

Wilcoxon signed-rank test, SD: Standard Deviation, sec; second, m; meter

Deep Sensation and Physical Activity condition tests of the Control Group before and after the intervention has shown as mean and minus plus standard deviation in Table 5.5. There were no statistically significant differences in diapason(p=0.91) and 60 degrees (p=0.36). Still, there were statistically significant changes in 30 degrees (p<0.05), 90 degrees (p<0.05), 6-minute walking test(p<0.05), Physical Activity Scale for Elderly(p<0.05), The Western Ontario and McMaster Universities Arthritis Index (p<0.05).

Table 5.5. Deep Sensation Assessment and Physical Activity Condition tests of the Control Group at baseline and after the intervention

	Baseline	After		
Variables	Mean±SD	Mean±SD	z	p-value
Diapason(sec)	5.28±3.16	5.39±3.27	-0.10	0.91
30 degrees	9.53±5.19	7.55±5.59	-2.12	**0.03**
60 degrees	5.15±3.81	3.97±1.56	-0.90	0.36
90 degrees	4.23±7.93	1.06±1.89	-2.27	**0.02**
6MWT(m)	220.03±91.64	248.92±70.69	-2.27	**0.02**
PASE	32.61±32.24	41.15±38.17	-2.67	**0.00**
WOMAC	41.34±13.34	35.25±13.92	-3.06	**0.00**

Wilcoxon signed-rank test, SD: Standard Deviation, sec; second, m; meter

Mann-Whitney U test was used to compare the deep sensation and physical activity condition before and after differences in between groups. Results are shown as mean and minus plus standard deviation in Table 5.6. There were no statistically significant differences in 30-degree (p=0.137), 60-degree (p=0.091), 90 degrees (p=0.456), and 6-minute walking tests (p=0.109). Still, there were statistically significant differences in diapason(p<0.05), Physical Activity Scale for Elderly(p<0.05), and The Western

Ontario and McMaster Universities Arthritis Index ($p<0.05$).

Table 5.6. Comparison of Deep Sensation Assessment and Physical Activity Condition differences between groups after the intervention

	Cycle Ergometer	Control		
	Difference Δ			
Variables	Mean±SD	Mean±SD	f value	p value
Diapason(sec)	2.93±1.86	0.10±3.35	6.637	**0.017**
30 degree	-6.28±3.89	-2.08±8.58	2.385	0.137
60 degree	-3.66±2.16	-1.17±4.43	3.102	0.091
90 degree	-1.31±2.02	-3.16±8.21	0.574	0.456
6MWT(m)	60.08±44.15	28.88±49.07	2.77	0.109
PASE	21.58±19.53	8.53±10.69	4.385	**0.047**
WOMAC	-27.34±7.79	-6.08±3.42	80.064	**0.000**

Wilcoxon signed-rank test , SD: Standard Deviation, sec; second, m; meter

6. DISCUSSION

In this study, we observed that Cycle Ergometer with Biofeedback had positive impacts on knee proprioception, physical activity level, muscle strength, lower extremity awareness, weight transfer, and exercise participation of elderly individuals with KO. Adding a Cycle Ergometer alongside the conventional treatment improved the deep sense, PASE, and OA index scores in our study. The study showed that the position sense of both groups improved positively at 30-degree and 90-degree extension. On the other hand, the vibration sense developed only in the CEG group when the two groups compared.

In a randomized controlled trial conducted in a kinesiology laboratory, the researchers aimed to investigate whether weight-bearing (WB) exercise would result in changes in knee reposition error, WOMAC function scale, walking speed, and muscle torque, compared to non-weight-bearing (NWB) exercise in individuals with KO. One hundred six participants were randomly assigned to either the WB exercise group, the NWB exercise group, or a control group (no exercise). Over eight weeks, both exercise groups underwent knee extension-flexion exercise programs. The results showed significant improvements in all outcomes for both the WB exercise and NWB exercise groups, except for knee reposition error, which showed greater improvement in the WB exercise group. On the other hand, the control group did not show any improvements. The WB exercise group demonstrated enhanced position sense, which may be advantageous for performing complex walking tasks [97].

To investigate the influence of receptor functionality on position sense, other researchers conducted a study to evaluate the precision of knee proprioception both pre and post exercise session on the Cycle Ergometer. Their sample comprised 32 healthy individuals, and they employed four different protocols, each combining two tasks one of them is using the contralateral leg, and other one utilizing a leg scheme displayed on a screen and two positioning methods (active and passive). The outcomes revealed a notable improvement in position sense following exercise. These findings suggest that the benefits of exercise on motor performance extend beyond enhanced muscular properties, as they also contribute to an enhanced kinesthetic sensibility, regardless of the underlying mechanisms involved [98].

In our study, thera-train device instantly showed which side is giving weight to

the pedal, and patients tried to reduce the difference between the two legs with this feedback and weigh the two sides equally. We estimate that this biofeedback increases body awareness through the sense of proprioception, thus increasing the sense of vibration in the knee. However, there was no study in the literature on the development of knee vibration sensation and using Cycle Ergometry. Contrary to studies mentioned above, we observed that exercising with the Cycle Ergometer did not affect the joint position sense in 15 session treatment ($p>0.05$). In future studies, differences in kinesthesia sensation between the long and short term Cycle Ergometer exercise can be included in addition to deep sense evaluations.

Multiple factors contribute to changes in proprioception, and nutrition and vitamin levels play a crucial role. Vitamin B12 deficiency, in particular, has been linked to various dysfunctions affecting multiple organ systems, including the nervous system. Patients with vitamin B12 deficiency commonly experience abnormalities in proprioception, vibration, and upper motor neuron signs abnormalities. Recent observations suggest that the posterior columns, primarily in the cervical and thoracic areas, are predominantly affected, as evidenced by hyperintense lesions in the spinal cord's posterior columns on MRI imaging [99]. The prevalence of vitamin B12 deficiency varies across different age groups. In general, it affects a small percentage of individuals aged 20-39 years (≤3%), a slightly higher percentage in the age group of 40-59 years (≈4%), and a higher percentage in persons aged 70 years or older (≈6%). However, in the UK surveys, the prevalence of vitamin B12 deficiency (serum B-12 ≤ 150 pmol/L) increased significantly after age 69. Approximately 1 in 20 people aged 65-74 and at least 1 in 10 individuals aged 75 years or older were affected [100]. In further studies vitamin B12 values should be observed in addition to deep sense evaluations.

In our study, the PASE score increased in both groups ($p<0.05$). The movement functions and exercise capacities of the participants improved. In addition, the PASE value showed even more improvement in CEG when the two groups were compared ($p<0.05$). A study investigates the effect of low and high-intensity cycling in older people. They divided thirty-nine individuals (with an average age of 71 ± 6.9 years) who experienced knee pain and were diagnosed with osteoarthritis into two groups randomly: a high-intensity exercise group (exercising at 70% of their heart rate reserve HRR) and a low-intensity exercise group (exercising at 40% HRR). They participated in a 10-week stationary cycling program for 25 minutes thrice weekly. According to the

analysis of variance, both groups significantly improved on several of different parameters, including the timed chair rise, the 6-minute walk test, the range of walking speeds, general pain reduction, and aerobic capacity. There was no significant variance among the two groups. Pain reports showed that neither group's acute pain increased as a result of pedaling. Pedaling can thus be thought of as an alternate form of exercise for those who have KO. Low-intensity cycling has been demonstrated to be just as helpful as high-intensity cycling in improving functionality, pain reduction, gait, and improving aerobic capacity [101]. According to the results of a study on KO and depression, it was determined that kinesiophobia negatively affects the quality of life and anxiety-depression status in patients with KO. This study was performed on 80 patients planning to undergo surgery for KO. The mean age of the participants was 65.31±8.19 years, which is close to our participants' average age. In the study, participants' pain status was evaluated using the Visual Pain Scale, anxiety and depression status using the Hospital Anxiety Depression Scale (HADS), kinesiophobia status using the Tampa Kinesiophobia Questionnaire Short Form (TCS-11), and quality of life using Short Form-12 (SF-12) Quality of Life. A positive correlation was found between kinesiophobia and anxiety and depression ($p<0.05$). In addition, a negative correlation was found between kinesiophobia and the role of physical condition, which is one of the sub-dimensions of SF-12, mental well-being, pain, general health, and energy-fatigue level ($p<0.05$) [102].

In light of these results, we can say that recommending appropriate exercise and patients' motivation are important while we are planning exercise programs to prevent fear-related inactivity. We believe that, in our study, the PASE value of the CEG group increased, as the Cycle Ergometer enables the patients to work on the lower extremities by sitting without putting a load on the hip joint and strengthening these muscles. Also biofeedback improved their motivation to do regular exercises. Although the CEG group showed improvement in the 6-minute walk test, there was no significant difference compared to the control group ($p>0.05$). A longer-term study can be conducted to observe the change in the 6MWT values of elderly individuals using Cycle Ergometers in the future.

In our study, we conducted that WOMAC scores were further reduced in the CEG group($p<0.05$). A study showed that inappropriate repetitive movements also affect the osteoarthritic joint. According to a cross-sectional study, underground coal miners face a higher risk of KO than the general population, with risk ratios ranging

from 1.9 to 13.0. This elevated risk is likely attributed to their frequent engagement in kneeling or squatting as part of their work activities. Similarly, construction workers, especially those requires to kneel down to complete their tasks, are at an increased risk of developing KO. [103,104].

It has been found that prolonged squatting significantly predisposes individuals to develop KO. Approximately 40% of men and 68% of women reported engaging in squatting activities for at least one hour per day at the age of 25. Prolonged squatting has been identified as a higher risk factor for tibiofemoral KO among older people. Furthermore, occupations involving squatting or kneeling for more than two hours daily have been associated with a twofold increase in the risk of moderate to severe radiographic KO [104]. Another study investigated the effect of applying manual therapy and cycle ergometry in addition to stretching and strengthening exercises in individuals over 50 years of age with KO. Patients came for 4 weeks, 2 times a week. 30 participants were divided into groups A and B. In addition to group A, manual therapy and low-intensity cycling ergometry were applied. As a result, group A showed greater improvement in pain, stiffness and physical function while measuring WOMAC and 6MWT. [105] In light of these researches, suitable exercise for the patient who has KO plays an important role.

The positive side of the biofeedback Cycle Ergometer is that it allows patients to focus on placing equal weight on both legs. We especially told the patients that the number of pedaling cycles per minute (cadence) on the screen should not exceed 40-45 and that the most important thing is to equalize the bars that appear on the screen with proper weight transfer. Thus, the patients realized they performed better by turning slowly, and their heart rates did not rise too much. The fact that the heart rate did not increase allowed the patients to adapt to the exercise and do it regularly. Regular moderate exercise positively affected knee joint nutrition, muscle strength, and lower extremity endurance. For this reason, we believe that, in our study, the symptoms of osteoarthritis in the patients and WOMAC scores were further reduced in the CEG group.

With technology, patients participate in treatments more motivated and willingly. Especially in our study, simple visual feedback of weight bearing to elderly patients led them to do the exercise more accurately and confidently. At the same time, the usage of technological tools in the rehabilitation process has provided more reliable and objective results. When the patients noticed that they were transferring weight in the

wrong way while they were pedaling, they started to correct themselves. This experience had a very positive effect on the continuity and motivation of the participants.

Our study's limitations were that we could only follow the patients for 15 sessions. If we provided patients with more cycling sessions, we could monitor how deep sensory perception and osteoarthritis symptoms change in the long term. In addition, we had a relatively small sample size. The patients could only use the device when they came to our clinic. Difficult weather conditions, fatigue, and transportation difficulties were affecting the exercise performance of the elderly patients negatively, as it led to low energy levels and increased knee pain. Having a portable or take-home pedaling device could have contributed to a faster improvement in their performance and exercise more often.

7. CONCLUSION

In conclusion, the Biofeedback Cycle Ergometer might improve health, deep sensation parameters, body awareness, and quality of life in individuals with KO. Even though both groups improved statistically, the Cycle Ergometer Group showed that the biofeedback Cycle Ergometer usage improved physical activity scores and reduced the adverse effects of osteoarthritis better. Therefore, further studies, including larger sample sizes and long-term follow-ups, are needed to investigate the relationship between Cycle Ergometer and gait parameters, muscle strength, body awareness, and quality of life in older individuals. Using technological devices for rehabilitation positively affects patients' motivation and treatment results. Therefore, patients' motivation will positively impact their health status, increase their self-confidence, reduce their needs for others, and enable them to care for themselves. It will be very effective in the fight against inactivity-related obesity. Working with these types of devices provides more objective results. More intense technology usage in the future will shed light on rehabilitation methods and research. Thus, we believe that the effectiveness and importance of rehabilitation in health systems will increase, and the need for other treatments, such as surgery, will reduce.

Conflict of interest

The author declares no conflict of interest.

8. SOURCES

1. Brandt KD, Dieppe P, Radin EL. Etiopathogenesis of osteoarthritis. Rheum Dis Clin N Am 2008;34:531-59

2. Zhang W, Moskowitz RW, Nuki G, Abramson S, Altman RD, Arden N, et al. OARSI recommendations for managing hip and knee osteoarthritis, Part I: Critical appraisal of existing treatment guidelines and systematic review of current research evidence. Osteoarthritis Cartilage 2007;15:981-1000.

3. Lo, J., Chan, L., & Flynn, S. (2020). *A Systematic Review of the Incidence, Prevalence, Costs, and Activity/Work Limitations of Amputation, Osteoarthritis, Rheumatoid Arthritis, Back Pain, Multiple Sclerosis, Spinal Cord Injury, Stroke, and Traumatic Brain Injury in the United States: A 2019 Update. Archives of Physical Medicine and Rehabilitation.*doi:10.1016/j.apmr.2020.04.001

4. Swain, S., Sarmanova, A., Mallen, C., Kuo, C. F., Coupland, C., Doherty, M., & Zhang, W. (2020). Trends in incidence and prevalence of osteoarthritis in the United Kingdom: findings from the Clinical Practice Research Datalink (CPRD). *Osteoarthritis and cartilage*, *28*(6), 792-801.

5. Demiriz, S. Y., & Sarıkaya, S. Diz Osteoartriti Hastalarında Tanı ve Kılavuzlar Işığında Güncel Tedavi. *Batı Karadeniz Tıp Dergisi*, *5*(2), 115-124

6. Dıraçoğlu, D., Aydın, A. R., & Başkent, A. (2005). Sağlıklı kişilerde ve diz osteoartritli hastalarda propriosepsiyon duyusunun karşılaştırılması. *Türkiye Fiziksel Tıp ve Rehabilitasyon Dergisi*, *51*(3), 90-93.

7. Sharma L. Proprioceptive impairment in knee osteoarthritis. Rheum Dis Clin North Am 1999;25(2):299-314.

8. Irrgang JJ, Neri R. The Rationale for open and closed kinetic chain ac- activities for restoration of proprioception and neuromuscular control following injury. In: Lephard SM, Fu FH, editors. Proprioception and neuromuscular control in joint stability. 1st ed. Pittsburg: Human Kinetics; 2000. p. 363-72

9. Petrella RJ, Lattanzio PJ, Nelson MG. Effect of age and activity on knee joint proprioception. Am J Phys Med Rehabil 1997;76(3):235-41.

10. Radin EL, Yang KH, Riegger C, Kish VL: Relationship between lower limb dynamics and knee joint pain. J Orthop Res 1991;9(3):398-405.

11. Kraus VB, Blanco FJ, Englund M, Karsdal MA, Lohmander LS. Call for standardized definitions of osteoarthritis and risk stratification for clinical trials and clinical use. Osteoarthritis Cartilage. 2015;23(8):1233–1241. [PubMed: 25865392]

12. Hawker G Osteoarthritis: a serious disease Osteoarthris Research Society International 2016. https:// www.oarsi.org/research/oa-serious-disease.

13. vanSaaseJLCM,vanRomundeLKJ,CatsA,etal.:Epidemiology of osteoarthritis: Zoetermeer survey. Comparison of radiological osteoarthritis in a Dutch population with that in 10 other popula- tions. Ann Rheum Dis 1989; 48: 271–80.

14. HannanMT,FelsonDT,PincusT:Analysisofthediscordance between radiographic changes and knee pain in osteoarthritis of the knee. J Rheumatol 2000; 27: 1513–17.

15. Hackenbroch MH. *Arthrosen.* Georg Thieme Verlag; 2002.

16. Greene GW, Banquy X, Lee DW, Lowrey DD, Yu J, Israelachvili JN. Adaptive mechanically controlled lubrication mechanism found in articular joints. Proc Natl Acad Sci U S A. 2011; 108:5255–9. [PubMed: 21383143]

17. Andriacchi TP, Mundermann A, Smith RL, Alexander EJ, Dyrby CO, Koo S. A framework for the in vivo pathomechanics of osteoarthritis at the knee. Ann Biomed Eng. 2004; 32:447–57. [PubMed: 15095819]

18. BuckwalterJA,MankinHJ:Articularcartilage.PartI:Tissue design and chondrocyte matrix interactions. J Bone Joint Surg 1997; 79-A: 600–11.

19. BuckwalterJA,MankinHJ:Articularcartilage.PartI:Degeneration and osteoarthrosis, repair, regeneration and transplantation. J Bone Joint Surg 1997; 79-A: 612–32.

20. Goldring MB, Marcu KB. Cartilage homeostasis in health and rheumatic diseases. Arthritis Res Ther. 2009; 11:224. [PubMed: 19519926]

21. Glasson SS, Askew R, Sheppard B, Carito B, Blanchet T, Ma HL, et al. Deletion of active ADAMTS5 prevents cartilage degradation in a murine model of osteoarthritis. Nature. 2005; 434:644–8. [PubMed: 15800624]

22. Wang, F., Liu, M., Wang, N., & Luo, J. (2022). G protein-coupled receptors in osteoarthritis. *Frontiers in Endocrinology*, *12*, 808835.

23. Lieberthal, J., Sambamurthy, N., & Scanzello, C. R. (2015). Inflammation in joint injury and post-traumatic osteoarthritis. *Osteoarthritis and cartilage*, *23*(11), 1825-1834.

24. Blagojevic M, Jinks C, Jeffery A, Jordan KP. Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. Osteoarthritis Cartilage. 2010; 18:24–33. [PubMed: 19751691]

25. Englund M, Guermazi A, Gale D, Hunter DJ, Aliabadi P, Clancy M, et al. Incidental meniscal findings on knee MRI in middle-aged and elderly persons. *N Engl J Med.* 2008;359:1108–15.[PMC free article] [PubMed] [Google Scholar]

26. Englund M, Guermazi A, Roemer FW, Aliabadi P, Yang M, Lewis CE, et al. Meniscal tear in knees without surgery and the development of radiographic osteoarthritis among middle-aged and elderly persons: The Multicenter Osteoarthritis Study. *Arthritis Rheum.* 2009;60:831–9. [PMC free article] [PubMed] [Google Scholar]

27. Hill CL, Seo GS, Gale D, Totterman S, Gale ME, Felson DT. Cruciate ligament integrity in osteoarthritis of the knee. *Arthritis Rheum.* 2005;52:794–9. [PubMed] [Google Scholar]

28. Loeser RF, Goldring SR, Scanzello CR, Goldring MB. Osteoarthritis: a disease of the joint as an organ. Arthritis Rheum. 2012 Jun;64(6):1697-707. doi: 10.1002/art.34453. Epub 2012 Mar 5. PMID: 22392533; PMCID: PMC3366018.

29. Watanabe A, Kanamori A, Ikeda K, Ochiai N. Histological evaluation and comparison of the anteromedial and posterolateral bundle of the human anterior cruciate ligament of the osteoarthritic knee joint. The Knee. 2011; 18:47–50. [PubMed: 20061154]

30. Mullaji AB, Marawar SV, Simha M, Jindal G. Cruciate ligaments in arthritic knees: a histologic study with radiologic correlation. The Journal of arthroplasty. 2008; 23:567–72. [PubMed: 18514876]

31. van der Kraan PM, van den Berg WB. Osteophytes: relevance and biology. Osteoarthritis Cartilage. 2007; 15:237–44. [PubMed: 17204437]

32. Sharma L, Song J, Felson DT, Cahue S, Shamiyeh E, Dunlop DD. The role of knee alignment in disease progression and functional decline in knee osteoarthritis. JAMA. 2001;286(2):188–195. [PubMed: 11448282]

33. 19. Taljanovic MS, Graham AR, Benjamin JB, et al. Bone marrow edema pattern in advanced hip osteoarthritis: quantitative assessment with magnetic resonance imaging and correlation with clinical examination, radiographic findings, and histopathology. Skeletal radiology. 2008;37(5):423–431. [PubMed: 18274742]

34. Brouwer, G. M., Tol, A. V., Bergink, A. P., Belo, J. N., Bernsen, R. M. D., Reijman, M., ... & Bierma‐Zeinstra, S. M. A. (2007). Association between valgus and varus alignment and the development and progression of radiographic osteoarthritis of the knee. *Arthritis & rheumatism*, *56*(4), 1204-1211.

35. Collins JE, Katz JN, Dervan EE, Losina E. Trajectories and risk profiles of pain in persons with radiographic, symptomatic knee osteoarthritis: data from the osteoarthritis initiative. Osteoarthritis Cartilage. 2014;22(5):622–630. [PubMed: 24662734]

36. Duncan R, Peat G, Thomas E, Wood L, Hay E, Croft P. Does isolated patellofemoral osteoarthritis matter? Osteoarthritis Cartilage. 2009;17(9):1151–1155. [PubMed: 19401244]

37. Bellamy N, Buchanan WW, Goldsmith CH, Campbel J, Stitt I: Vali- dation study of WOMAC: A health status instrument for measuring clinically-important patient-relevant outcomes following total hip or knee arthroplasty in osteoarthritis. J Orthop Rheumatol 1988; 1: 95–108.

38. Krämer KL, Maichl FP: Scores, Bewertungsschemata und Klassifi- kationen in Orthopädie und Traumatologie. Thieme, Stuttgart 1993.

39. Michael, J. W. P., Schlüter-Brust, K. U., & Eysel, P. (2010). The epidemiology, etiology, diagnosis, and treatment of osteoarthritis of the knee. *Deutsches Arzteblatt International*, *107*(9), 152.

40. Altman R, Asch E, Bloch D, et al. Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Diagnostic

and Therapeutic Criteria Committee of the American Rheumatism Association. Arthritis Rheum. 1986;29(8):1039–1049. [PubMed: 3741515]

41. Hunter DJ, Zhang W, Conaghan PG, et al. Systematic review of the concurrent and predictive validity of MRI biomarkers in OA. Osteoarthritis Cartilage. 2011;19(5):557–588. [PubMed: 21396463]

42. Wang, Y., Li, S., Zhao, B., Zhang, J., Yang, Y., & Li, B. (2022). A ResNet‐based approach for accurate radiographic diagnosis of knee osteoarthritis. *CAAI Transactions on Intelligence Technology*, *7*(3), 512-521.

43. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16(4):494–502. [PubMed: 13498604]

44. Bannuru RR, Osani MC, Vaysbrot EE, et al. OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis. Osteoarthritis Cartilage. 2019;27(11):1578–1589. [PubMed: 31278997]

45. Fernandes L, Hagen KB, Bijlsma JW, et al. EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. Ann Rheum Dis. 2013;72(7):1125–1135. [PubMed: 23595142]

46. Kolasinski SL, Neogi T, Hochberg MC, et al. 2019 American College of Rheumatology/Arthritis Foundation Guideline for the Management of Osteoarthritis of the Hand, Hip, and Knee. Arthritis & Rheumatology. 2020;72(2):220–233. [PubMed: 31908163]

47. Deutsche Gesellschaft für Orthopädie und orthopädische Chirurgie und Berufsverband der Ärzte für Orthopädie: Leitlinien der Orthopädie: Gonarthrose. Deutscher Ärzte-Verlag 2002; 2nd Edition

48. Wu, Y., Zhu, S., Lv, Z., Kan, S., Wu, Q., Song, W., Feng, S. (2019). *Effects of therapeutic ultrasound for knee osteoarthritis: a systematic review and meta-analysis. Clinical Rehabilitation, 026921551986649*.doi:10.1177/0269215519866494

49. Lawson D, Degani AM, Lee K, Beer EI, Gohlke KE, Hamidi KN, Coler MA, Tews

NM. Use of transcutaneous electrical nerve stimulation along with functional tasks for immediate pain relief in individuals with knee osteoarthritis. Eur J Pain. 2022 Mar;26(3):754-765. doi: 10.1002/ejp.1903. Epub 2022 Jan 6. PMID: 34964537.

50. Gibson W, Wand BM, O'Connell NE. Transcutaneous electrical nerve stimulation (TENS) for neuropathic pain in adults. Cochrane Database Syst Rev. 2017 Sep 14;9(9):CD011976. [PMC free article] [PubMed]

51. Johnson M. Transcutaneous electrical nerve stimulation: review of effectiveness. Nurs Stand. 2014 Jun 10;28(40):44-53. [PubMed]

52. Johnson MI, Paley CA, Howe TE, Sluka KA. Transcutaneous electrical nerve stimulation for acute pain. Cochrane Database Syst Rev. 2015 Jun 15;2015(6):CD006142. [PMC free article] [PubMed]

53. Sluka, K. A., & Walsh, D. (2003). Transcutaneous electrical nerve stimulation: basic science mechanisms and clinical effectiveness. *The Journal of pain*, *4*(3), 109-121.

54. Williams AR. Production and transmission of ultrasound. Physiotherapy. 1987;73(3): 113-116.

55. Baker KG, Robertson VJ, Duck FA. A review of therapeutic ultrasound: biophysical effects. Physical therapy. 2001 Jul 1;81(7):1351-8.

56. Ter Haar G. Therapeutic ultrasound. European Journal of ultrasound. 1999 Mar 1;9(1):3-9.

57. Nussbaum EL. Ultrasound: to heat or not to heat—that is the question.Physical Therapy Reviews. 1997 Jun 1;2(2):59-72.

58. Watson T. The role of electrotherapy in contemporary physiotherapy practice.Manual therapy. 2000 Aug 1;5(3):132-41.

59. Val Robertson, Alex Ward, John Low John Low Ann Reed, Electrotherapy Explained: Principles and Practice. 4th Edition. Butterworth-Heinemann,2006

60. Dyson M, Suckling J. Stimulation of tissue repair by ultrasound: a survey of the

mechanisms involved. Physiotherapy. 1978 Apr;64(4):105–8.

61. Dinno MA, Dyson M, Young SR, Mortimer AJ, Hart J, Crum LA. The significance of membrane changes in the safe and effective use of therapeutic and diagnostic ultrasound. Physics in Medicine & Biology. 1989 Nov;34(11):1543.

62. Young SR, Dyson M. Macrophage responsiveness to therapeutic ultrasound. Ultrasound in medicine & biology. 1990 Jan 1;16(8):809-16.

63. Maxwell L. Therapeutic ultrasound: its effects on the cellular and molecular mechanisms of inflammation and repair. Physiotherapy. 1992 Jun 10;78(6):421-6.

64. Harvey W, DYSON M, Pond JB, Grahame R. The stimulation of protein synthesis in human fibroblasts by therapeutic ultrasound. Rheumatology. 1975 Nov 1;14(4):237.

65. Brouwer RW, van Raaij TM, Jakma TT, Verhagen AP, Verhaar JAN, Bierma-Zeinstra SMA: Braces and orthoses for treating osteoar- thritis of the knee. Cochrane Database Syst Rev 2005; 1, CD004020

66. DEMİRİZ, S. Y., & SARIKAYA, S. (2021). Diz Osteoartriti Hastalarında Tanı ve Kılavuzlar Işığında Güncel Tedavi. *Batı Karadeniz Tıp Dergisi*, *5*(2), 115-124.

67. Lanza FL, Chan FK, Quigley EM. Guidelines for prevention of NSAID-related ulcer complications. The American journal of gastroenterology. 2009;104(3):728–738. [PubMed: 19240698]

68. EllamyN,CambellJ,RobinsonV,etal.:Intraarticularcorticoste- roid for treatment of osteoarthritis of the knee. Cochrane Data- base Syst Rev 2006; 2: CD005328

69. e25. RichmondJ,HunterD,IrrgangJ,etal.:Treatmentofosteoarthritis of the knee (nonarthroplasty). J Am Acad Orthop Surg 2009; 17: 591–600.

70. e26. GeirssonAJ,StatkeviciusS,VíkingssonA.:Septicarthritisin Iceland 1990–2002: increasing incidence due to iatrogenic infections. Ann Rheum Dis. 2008; 67: 638–43.

71. Deyle GD, Allen CS, Allison SC, et al. Physical Therapy versus Glucocorticoid Injection for Osteoarthritis of the Knee. The New England journal of medicine.

2020;382(15):1420–1429. [PubMed: 32268027]

72. Hochberg MC, Wohlreich M, Gaynor P, Hanna S, Risser R. Clinically Relevant Outcomes Based on Analysis of Pooled Data from 2 Trials of Duloxetine in Patients with Knee Osteoarthritis. The Journal of Rheumatology. 2012;39(2):352. [PubMed: 22133624]

73. 60. Osani MC, Bannuru RR. Efficacy and safety of duloxetine in osteoarthritis: a systematic review and meta-analysis. Korean J Intern Med. 2019;34(5):966–973. [PubMed: 30871298]

74. Moseley JB, O'Malley K, Petersen NJ, et al.: A controlled trial of arthroscopic surgery for osteoarthritis of the knee. N Engl J Med 2002; 347: 81–8.

75. Burmann MS, Finkelstein H, Mayer L: Arthroscopy of the knee joint. J Bone Joint Surg 1934; 16: 255–68.

76. Outerbridge RE: The etiology of chondromalacia patellae. J Bone Joint Surg (Br) 1961; 43: 752–7.

77. Magnuson PB: Joint debridement and surgical treatment of degenerative arthritis. Gynecol Obstet 1941; 73: 1–9.

78. Jakob RP: Instabilitätsbedingte Gonarthrose: Spezielle Indikationen für Osteotomien bei der Behandlung des instabilen Kniegelenks. In: Jakob RP, Stäubli HU (eds.): Kniegelenk und Kreuzbänder. Berlin: Springer 1990.

79. Akinrodoye, M. A., & Lui, F. (2020). Neuroanatomy, somatic nervous system.

80. Brodal A. The Somatic Afferent Pathways. *Neurological Anatomy*. 2nd ed. New York: Oxford University Press; 1969. 31-116.

81. Biga, M.L., Dawson S., Harwel A., *Anatomy & Physiology* (2019) Oregon State University Ecampus 903-905

82. Afifi AK, Bergman RA. Ch. 3, Spinal Cord; Ch. 5, Medulla Oblongata; Ch. 17 Cerebral Cortex. Hefta J, Melvin S, Eds. *Functional Neuroanatomy*. New York, St. Louis, San Francisco: The McGraw-Hill Companies, Inc; 1998. 3,5,17.

83. Parent A. Receptors and Effectors, Peripheral Nervous System, Spinal Cord, Cerebral Cortex. Coryell P, Napora LS, Adin RH, Eds. *Carpenter's Human Neuroanatomy*. 9th ed. Media, PA: Williams and Wilkins; 1996. 7, 235-61; 8, 262-92; 20, 864-936.

84. Johns, P. (2014). *Sensory and motor pathways. Clinical Neuroscience, 49–59.* doi:10.1016/b978-0-443-10321-6.00004-7

85. Svensson, M., Lind, V., & Löfgren Harringe, M. (2019). Measurement of knee joint range of motion with a digital goniometer: A reliability study. *Physiotherapy Research International*, *24*(2), e1765.

86. Erden, A., Malkoç, A., & Akgül Kocabal, A. (2016). Investigation of the relationship between kinesiophobia, pain, anxiety-depression status and quality of life in patients with knee osteoarthritis before surgery. *International Refereed Journal of Orthopaedic Traumata and Sports Medicine*, 1-17.

87. Santos BF, Souza HC, Miranda AP, Cipriano FG, Gastaldi AC. Performance in the 6-minute walk test and postoperative pulmonary complications in pulmonary surgery: an observational study. Braz J Phys Ther. 2016 Jan-Feb;20(1):66-72. [PMC free article] [PubMed]

88. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002 Jul 01;166(1):111-7. [PubMed]

89. Pankoff BA, Overend TJ, Lucy SD, White KP. Reliability of the six-minute walk test in people with fibromyalgia. Arthritis Care Res. 2000 Oct;13(5):291-5. [PubMed]

90. Falvo MJ, Earhart GM. Six-minute walk distance in persons with Parkinson disease: a hierarchical regression model. Arch Phys Med Rehabil. 2009 Jun;90(6):1004-8.[PubMed]

91. Goldman MD, Marrie RA, Cohen JA. Evaluation of the six-minute walk in multiple sclerosis subjects and healthy controls. Mult Scler. 2008 Apr;14(3):383-90. [PubMed]

92. Kennedy, D. M., Stratford, P. W., et al. "Assessing stability and change of four performance measures: a longitudinal study evaluating outcome following total hip and knee arthroplasty." BMC Musculoskelet Disord 2005 6: 3

93. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the elderly (PASE): Development and evaluation. Journal of Clinical Epidemiology. 1993 Feb 1;46(2):153–62.

94. Ayvat, E., Kilinc, M., & Kirdi, N. (2017). The Turkish version of the Physical Activity Scale for theElderly (PASE): its cultural adaptation, validation, and reliability. *Turkish journal of medical sciences*, *47*(3), 908-915.

95. Basaran, S., Guzel, R., Seydaoglu, G., & Guler-Uysal, F. (2010). Validity, reliability, and comparison of the WOMAC osteoarthritis index and Lequesne algofunctional index in Turkish patients with hip or knee osteoarthritis. *Clinical rheumatology*, *29*(7), 749-756.

96. McConnell, S., Kolopack, P., & Davis, A. M. (2001). *The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC): a review of its utility and measurement properties. Arthritis & Rheumatism, 45(5), 453–461.*doi:10.1002/1529-0131(200110)45:5<453::aid-art365>3.0.co;2-w

97. Jan, M. H., Lin, C. H., Lin, Y. F., Lin, J. J., & Lin, D. H. (2009). Effects of weight-bearing versus nonweight-bearing exercise on function, walking speed, and position sense in participants with knee osteoarthritis: a randomized controlled trial. *Archives of physical medicine and rehabilitation*, *90*(6), 897-904.

98. Bouët, V., & Gahéry, Y. (2000). Muscular exercise improves knee position sense in humans. *Neuroscience letters*, *289*(2), 143-146.

99. Serin, H. M., & Arslan, E. A. (2019). Neurological symptoms of vitamin B12 deficiency: analysis of pediatric patients. *Acta Clinica Croatica*, *58*(2), 295.

100. Allen, L. H. (2009). How common is vitamin B-12 deficiency?. *The American journal of clinical nutrition*, *89*(2), 693S-696S.

101. Mangione, K. K., McCully, K., Gloviak, A., Lefebvre, I., Hofmann, M., & Craik, R. (1999). The effects of high-intensity and low-intensity cycle ergometry in older adults with knee osteoarthritis. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *54*(4), M184-M190.

102. Erden, A., Malkoç, A., & Akgül Kocabal, A. (2016). Investigation of the relationship between kinesiophobia, pain, anxiety-depression status and quality of

life in patients with knee osteoarthritis before surgery. *International Refereed Journal of Orthopaedic Traumata and Sports Medicine*, 1-17.

103. KirkesovJensenL,MilckelsenS,LoftIP,etal.:Radiographicknee osteoarthritis in floorlayers and carpenters. Scand J Work Environ 2000; 26: 257–62.

104. GrotleM,HagenKB,NatvigB,DahlFA,KvienTK:Obesityand osteoarthritis in knee, hip and/or hand: An epidemiological study in the general population with 10 years follow-up. BMC Musculo- skelet Disord. 2008; 9: 132.

105. *Heidari, B. (2011). Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I. *Caspian journal of internal medicine*, *2*(2), 205.

106. RAJ, L. D., & MILTON, A.(2017) Effectiveness of Manual Physical Therapy and Low Intensity Cycle Ergometry In Improving Paiın, Stiffness, Physical Function, And Functional Exercise Capacity In Adult With Osteoarthritis Knee. International Journal of Medical and Exercise Science, Vol 3 (3), 354-366.

APPENDIX A: ETHICAL COMMITTEE APPROVAL

T.C.
YEDİTEPE ÜNİVERSİTESİ REKTÖRLÜĞÜ
Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu

Sayı : E.83321821-805.02.03-51
Konu : Etik Kurul Karar Yazısı

Sayın Dr. Öğr. Üyesi Elif Develi

Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kuruluna etik onay için başvuru yapılmış olan araştırma önerisinin başlığı, araştırmacılar, başvuru numarası, sunulan belgeler ve toplantı bilgileri aşağıda yer almaktadır. İlgili araştırma önerisi, etik kurulumuz üyeleri tarafından değerlendirilmiş olup, etik ve bilimsel açıdan **UYGUN** olduğuna karar verilmiştir.

Araştırma Başlığı:	**Biofeedback Bisiklet Ergometresinin Diz Osteoartritli Hastalarda Derin Duyu Üzerine Etkisi**
Araştırmacılar:	**Nilay Aral, Dr. Öğr. Üyesi Elif Develi, Prof. Dr. Gülseren Derya Akyüzf**
Başvuru Numarası:	**202207Y0269**

TOPLANTI BİLGİLERİ			
Toplantı Tarihi:	08.07.2022	**Toplantı Yeri:**	Çevirim içi (Google Meet)

SUNULAN BELGELER
Islak imzalı başvuru dosyası, CD veya USB belleğe kaydedilmiş başvuru dosyası ve elektronik başvuru
Araştırma başlığı ve araştırmacıların isimleri
Başvuru dilekçesi
Başvuru formu
Araştırmanın;
• Niteliği
• Önemi ve özgün değeri
• Amaç ve hedefleri
• Yöntemi
• Yönetimi
• Yaygın etkisi
• Araştırma bütçesi (Mevcutsa)
• Süresi ve uygunluğu (Zaman cetveli)
• Kaynakları

Bilgilendirilmiş Gönüllü Olur Formu (yapılan araştırmaya özel olarak hazırlanmış)
Taahhütname-1 Araştırmanın yapılacağı kurumdan izin alma sorumluluğunun araştırmacılara ait olduğuna dair taahhüt
Taahhütname-2 Dünya Tıp Birliği Helsinki Bildirgesinin son versiyonunun ve Sağlık Bakanlığı'nın ilgili tüm kılavuzlarının okunmasına dair taahhüt
Taahhütname-3 Daha önce yapılmış etik kurul başvuruları mevcut olup olmadığına dair taahhüt
Taahhütname-4 Araştırma sırasında araştırma bütçesinde yer almayan ve gönüllünün kendisine veya Sosyal Güvenlik Kurumuna ek yük getirecek hiçbir işlem uygulanmayacağına dair taahhüt
Taahhütname-5 COVID-19 hastalarında tedavi yaklaşımları ve bilimsel araştırmalar genelgesi okunmasına dair taahhüt
Taahhütname-6 Millî Eğitim Bakanlığı Araştırma Uygulama İzinleri konulu yazının okunmasına dair taahhüt
Araştırmacıların her birisine ait özgeçmiş formu
Ek belgeler (Varsa kullanılan ölçek)

Prof. Dr. Didem ÖZDEMİR ÖZENEN
Başkan

Doç. Dr. Gökhan ERTAŞ
Başkan Yardımcısı

Doç. Dr. Elif SUNGURTEKİN EKÇİ
Raportör

Doç. Dr. Mehmet Engin CELEP
Üye

Doç. Dr. Binnur OKAN BAKIR
Üye

Dr. Öğr. Üyesi Elif Çiğdem KELEŞ
Üye

Dr. Öğr. Üyesi Emine Nur ÖZDAMAR
Üye

Dr. Öğr. Üyesi Sevim ŞEN
Üye

Bu belge, güvenli elektronik imza ile imzalanmıştır.
Belge Doğrulama Adresi : http://belgedogrulama.yeditepe.edu.tr/bg.aspx?id=D0B1A0CE-0AA4-4A1A-B86F-E2BE27B97A2D

Yeditepe Üniversitesi 26 Ağustos Yerleşimi, İnönü Mahallesi Kayışdağı Caddesi 34755
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Kep Adresi : yeditepeuniversitesi@hs03.kep.tr

Bilgi İçin: Sinem ARI
Unvan: Uzman Yardımcısı
Telefon No:

APPENDIX B: INFORMED WRITTEN CONSENT

YEDİTEPE ÜNİVERSİTESİ

EK 1. BİLGİLENDİRİLMİŞ ONAM FORMU

Araştırmanın Adı: Biofeedback Bisiklet Ergometrisinin Diz Osteoartritli Hastalarda Derin Duyu Üzerine Etkisi

Sayın Katılımcı,

Yukarıda adı yazılı araştırmaya katılmak üzere davet edilmiş bulunmaktasınız. Çalışmaya katılıp katılmama kararı tamamen size aittir. Katılmak isteyip istemediğinize karar vermeden önce araştırmanın neden yapıldığını, bilgilerinizin nasıl kullanılacağını, çalışmanın neler içerdiğini olası yararları ve risklerini ya da rahatsızlık verebilecek yönlerini anlamanız önemlidir. Lütfen aşağıdaki bilgileri okumak için zaman ayırınız. Sorularınız olursa sorunuz ve açık yanıtlar isteyiniz.

Bu araştırma ile diz osteortritli hastalarda bisiklet ergometresinin derin duyu üzerine etkisinin araştırılması hedeflenmiştir. Fiziksel aktivite düzeyinizin belirlenebilmesi için Yaşlılar için Fiziksel Aktivite Skalası (PASE), osteoartrit durumunuz için WOMAC indeksi, günlük yaşam aktivitesi durumunuzu ölçmek için 6 dakikalık yürüme testi ve demografik bilgileriniz için demografik onam formunu doldurmanız istenecektir. Diz eklemi pozisyon hissini ölçmek amacıyla elektronik gonyometre; vibrasyon hissini oluşturmak için diapozom ve süre ölçümü için kronometre kullanılacaktır. Diz osteoartritiniz için 20 dakika TENS akımı ve 5 dakika Ultrason uygulanacaktır. Seçilmiş olduğunuz gruba bağlı olarak, Thera-train bisiklet ergometresi ile 20 dakika pedal çevirmeniz istenecektir. Araştırma için Yeditepe Üniversitesinden ve Sante tıp merkezinden izin alınmıştır. Araştırmaya sizin dışınızda 39 kişi katılacaktır. Sizden bu çalışmaya 3 hafta (haftada 5 kez) katılmanız istenecektir. Bunun size ve yakınlarınıza zararı olmayacaktır. Bu çalışmaya katılmak için herhangi bir parasal yük altına girmeyeceksiniz.

Bu araştırmaya katılıp katılmamakta tümü ile özgürsünüz. Gerek duyduğunuz tüm bilgileri istemeye ve doğru, açık, anlaşılır bilgi almaya hakkınız vardır. Araştırmaya katılmayı istemezseniz burada size verilen hizmeti olumlu yada olumsuz şekilde etkilemeyecektir. Gerekli gördüğünüz takdirde araştırmanın herhangi bir kısmında katılımcı araştırmadan çıkabilir, araştırmacı çalışmayı sonlandırabilir. Araştırmanın tüm aşamalarında kimlik bilgileriniz gizli tutulacaktır. Araştırma kapsamında elde edilen bilgiler bilimsel amaçlarla kullanılabilir, gizlilik kurallarına uymak kaydıyla sunulabilir ve yayınlanabilir.

Araştırma ile ilgili daha fazla bilgiye ihtiyaç duyarsanız araştırma yürütücüsüne nilay.aral@std.yeditepe.edu.tr e-posta adresi veya 05[redacted] numaralı telefondan; sorumlu araştırmacıya elif.ustun@yeditepe.edu.tr e-posta adresi veya 05[redacted]3 numaralı telefondan ulaşabilirsiniz.

Yukarıda yer alan ve araştırmaya başlamadan önce katılımcılara verilmesi gereken bilgileri içeren metni okudum (ya da sözlü dinledim). Araştırma kapsamında elde edilen şahsıma ait bilgilerin bilimsel amaçlarla kullanılmasını, gizlilik kurallarına uymak kaydıyla sunulmasını ve yayınlanmasını, hiçbir baskı ve zorlama altında kalmaksızın, kendi özgür irademle kabul ettiğimi beyan ederim.

Katılımcı;	**Tanık:**	**Araştırma Yürütücüsü;**
İmza/Tarih:	İmza/Tarih:	İmza/Tarih:
Adı-Soyadı:	Adı-Soyadı:	Adı-Soyadı: Fzt. Nilay ARAL
Telefon No:	Telefon No:	Telefon No: 05344805231

APPENDIX C: DEMOGRAPHIC INFORMATION

Demografik Bilgi Anketi

Tarih:…./…./……1)Hastanın Adı

Soyadı:

2)Yaş:
3) Cinsiyet: Kız Erkek
4) Boy uzunluğu (cm):
5) Vücut ağırlığı (kg) :
6) Dominant taraf:
El Sağ Sol
Ayak Sağ Sol
7)Medeni Durumunuz:

- **Hiç evlenmemiş**
- **Evli**
- **Boşanmış**
- **Ayrı yaşıyor**
- **Eşi ölmüş**

8)Eğitim durumunuz

- **Okuryazar değil**
- **İlköğretim**
- **Lise**
- **Üniversite ve üzeri**

9) Mesleğiniz:
10) Varsa kaç çocuğunuz var .....

- **Yok**

11) Sigara kullanıyor musunuz?
a)Hiç içmedim
b)Sigara içtim ama bıraktım
c)Halen içiyorum
b) Günde kaç adet sigara içiyorsunuz?.....adet/gün

12) Alkol kullanıyor musunuz?

- **Evet Hangi sıklıkla?.....**
- **Hayır**

13) Doktor tarafından teşhisi konulmuş herhangi bir sistemik rahatsızlığınız var mı?

- **Evet**
- **Hayır**

Cevabınız evet ise teşhis edilen hastalığınız aşağıdakilerden hangisi / hangileridir? (birden fazla seçim yapabilirsiniz.)

- **Kalp damar hastalıkları**
- **Şeker hastalığı**
- **Yüksek tansiyon**
- **Kanser**

- **Sindirim sistemi hastalıkları (karaciğer, mide, safra kesesi,...)**
- **Solunum sistemi hastalıkları (akciğer)**
- **Ruhsal sorunlar (depresyon, aşırı yeme, kusma,...)**
- **Endokrin (hormonal) hastalıklar**
- **Vitamin ve mineral yetersizlikleri (Demir, B12, D vitamini,...)**
- **Diğer : .....**

14) Düzenli olarak kullandığınız bir ilaç var mı?

- **Evet Nedir ? .....**
- **Hayır**

15)Şu an herhangi bir ağrı kesici ilaç kullanıyor musunuz?
Evet Ne zamandır? ……..
Hayır

16)Herhangi bir diz ameliyat geçirdiniz mi? Evet..... Belirtiniz Hayır
17)Hiç kaza geçirdiniz mi ? Evet.....Belirtiniz Hayır
18)Spor yapıyor musunuz? Yapıyorsanız ne sıklıkta?
Yapmıyorum
Ayda bir kez den az Ayda 2 kez ve fazla Haftada 1 kez
Haftada 2-3kez Haftada 4-5 kez Her gün
19) Egzersiz yapanlar için yaptığınız egzersiz her seferinde kaç dakika sürüyor ?
20 dk az 20-30 dk 30 – 60 dk 60 dk. dan fazla
20) Vücudunuzda ağrı hissediyor musunuz?

- **Evet Nerede?.....Ne Zamandır? ……**
- **Hayır**

APPENDIX D: 6 MINUTE WALKING TEST(6MWT), GONIOMETER AND DIAPASON TEST

Boy:

Ağırlık:

Kan basıncı: /

Testten önce alınan ilaçlar (doz ve süre):

Test sırasında ek oksijen:

Zaman ___:___ ___:___

Kalp Atış Hızı:

SpO2 %:

6 dakikadan önce durduruldu mu veya duraklatıldı mı?: (EVET ise nedeni)

Egzersizin sonundaki diğer semptomlar:

anjina baş dönmesi kalça, bacak veya baldır ağrısı

Tur sayısı: (60 metre)

Son kısmi tur: metre

6 dakikada yürünen toplam mesafe: metre

Öngörülen mesafe: metre

Öngörülen yüzde: %

Yorumlama (müdahale öncesi 6MWD ile karşılaştırma dahil)

Nefes Darlığı	Modifiye Borg Skalası			Yorgunluk
	0	Hiç yok	0	
	0,5	Çok çok hafif nefes darlığı var	0,5	
	1	Çok hafif	1	
	2	Hafif	2	
	3	Orta	3	
	4	Biraz şiddetli	4	
	5	Şiddetli	5	
	6		6	
	7	Çok Şiddetli	7	
	8		8	
	9	Çok çok şiddetli	9	
	10	Maksimal	10	

Gonyometre ölçümü

Diapozon ölçümü

APPENDIX E: PHYSICAL ACTIVITY SCALE FOR THE ELDERLY (PASE)

AYVAT et al. / Turk J Med Sci

BOŞ ZAMAN AKTİVİTELERİ

1. Son yedi gün içerisinde ne sıklıkta el işi yapmak, TV seyretmek, ya da kitap okumak gibi oturma aktivitelerinde bulundunuz?

[0.] HİÇ [1.] NADİREN (1 - 2 GÜN) [2.] BAZEN (3 - 4 GÜN) [3.] SIK SIK (5 - 7 GÜN)

Cevabınız Hiç ise 2.soruya geçiniz.

1a. Bu aktiviteler nelerdir?

— — — — — — — — — — — — — — — — — — —

1b. Ortalama olarak günde kaç saat bu oturma aktiviteleriyle meşgul oldunuz?

[1.] 1 SAATTEN AZ [2.] 1 FAKAT 2 SAATTEN AZ
[3.] 2 - 4 SAAT [4.] 4 SAATTEN FAZLA

2. Son yedi gün boyunca herhangi bir sebeple yürüyüş için evinizden veya bahçenizden ne sıklıkta dışarı çıktınız? Örneğin, egzersiz veya zevk için, işe gitmek için, köpek gezdirmek için vb.?

[0.] HİÇ [1.] NADİREN (1 - 2 GÜN) [2.] BAZEN (3 - 4 GÜN) [3.] SIK SIK (5 - 7 GÜN)

Cevabınız Hiç ise 3.soruya geçiniz.

2a. Ortalama olarak yürüyüşe günde kaç saat harcadınız?

[1.] 1 SAATTEN AZ [2.] 1 FAKAT 2 SAATTEN AZ
[3.] 2 - 4 SAAT [4.] 4 SAATTEN FAZLA

3. Son yedi gün boyunca, bowling, bilardo, yürüyüş (yanındakiyle sohbet edebilecek hızda), dart, atıcılık, masa tenisi, yüzme , bottan veya iskeleden balık tutma, müzikal bir programa katılmak, namaz kılmak ya da diğer benzer aktiviteler gibi hafif sporlarla / aktivitelerle / ibadet ile ne sıklıkta meşgul oldunuz?

[0.] HİÇ [1.] NADİREN (1 - 2 GÜN) [2.] BAZEN (3 - 4 GÜN) [3.] SIK SIK (5 - 7 GÜN)

Cevabınız Hiç ise 4.soruya geçiniz.

3a. Bu aktiviteler nelerdir ?

— — — — — — — — — — — — — — — — — — —

3b. Ortalama olarak günde kaç saat bu hafif sporlarla veya eğlence aktiviteleriyle meşgul oldunuz ?

[1.] 1 SAATTEN AZ [2.] 1 FAKAT 2 SAATTEN AZ
[3.] 2 - 4 SAAT [4.] 4 SAATTEN FAZLA

4. Son yedi gün boyunca çiftler tenisi, dans, avcılık, voleybol, bisiklete binme (egzersiz amaçlı değil de ulaşım amaçlı), tempolu yürüyüş veya diğer benzer aktiviteler gibi orta dereceli sporlar ve eğlence aktivileriyle ne sıklıkta meşgul oldunuz?

[0.] HİÇ [1.] NADİREN (1 - 2 GÜN) [2.] BAZEN (3 - 4 GÜN) [3.] SIK SIK (5 - 7 GÜN)

Cevabınız Hiç ise 5.soruya geçiniz.

4a. Bu aktiviteler nelerdir?

— — — — — — — — — — — — — — — — — — — —

4b. Ortalama olarak günde kaç saat orta derece spor ve eğlence aktiviteleriyle meşgul oldunuz ?

[1.] 1 SAATTEN AZ [2.] 1 FAKAT 2 SAATTEN AZ
[3.] 2 - 4 SAAT [4.] 4 SAATTEN FAZLA

5. Son yedi gün boyunca tempolu koşu, profesyonel yüzme, bisiklete binme (egzersiz amaçlı), tekli tenis, aerobik dans, basketbol, futbol, arazi yürüyüşü, kürek çekme, ip atlama ya da diğer benzer aktiviteler gibi ağır sporlarla ve eğlence aktiviteleriyle ne sıklıkta meşgul oldunuz?

[0.] HİÇ [1.] NADİREN (1 - 2 GÜN) [2.] BAZEN (3 - 4 GÜN) [3.] SIK SIK (5 - 7 GÜN)

5a. Bu aktiviteler nelerdir?

— — — — — — — — — — — — — — — — — — — —

5b. Ortalama olarak günde kaç saat bu ağır sporlarla ve eğlence aktiviteleriyle meşgul oldunuz?

[1.] 1 SAATTEN AZ [2.] 1 FAKAT 2 SAATTEN AZ
[3.] 2 - 4 SAAT [4.] 4 SAATTEN FAZLA

6. Son yedi gün boyunca özellikle kas gücünü ve dayanıklılığını arttırmak için ağırlık kaldırma, ağırlıklarla fizyoterapi, mekik, şınav ve benzerleri egzersizleri gibi ne sıklıkta yaptınız?

[1.] 1 SAATTEN AZ [2.] 1 FAKAT 2 SAATTEN AZ
[3.] 2 - 4 SAAT [4.] 4 SAATTEN FAZLA

Cevabınız Hiç ise 7.soruya geçiniz.

6a. Bu aktiviteler nelerdir?

— — — — — — — — — — — — — — — — — — — —

6b. Ortalama olarak, kas gücünü ve dayanıklılığını arttırmak için günde kaç saat egzersizle meşgul oldunuz ?

[1.] 1 SAATTEN AZ [2.] 1 FAKAT 2 SAATTEN AZ
[3.] 2 - 4 SAAT [4.] 4 SAATTEN FAZLA

EV İŞİ AKTİVİTELERİ

7. Son yedi gün boyunca toz alma, ütü yapma, yemek hazırlama, çamaşır yıkama - asma bulaşık yıkama - kurulama, gibi hiç hafif ev işleri yaptınız mı?

[1.] HAYIR [2.] EVET

8. Son yedi gün boyunca elektrik süpürgesiyle temizleme, yerleri silme , camları -duvarları slime, araba yıkamak, eşyaların yerlerini değiştirmek, ya da odun taşımak gibi ağır ev işleri ya da günlük işler yaptınız mı?

[1.] HAYIR [2.] EVET

9. Son yedi gün boyunca aşağıdaki aktivitelerden herhangi biriyle meşgul oldunuz mu?

Lütfen her maddeye EVET ya da HAYIR olarak cevap veriniz.

	HAYIR	EVET
a. Boyama, duvar kağıdı kaplama,elektrik işleri gibi ev tamiratları vb.	1	2
b. Kar ya da yaprak küreme, odun kesmek ve benzerlerini içeren çim veya bahçe bakımı	1	2
c. Bahçe işleri	1	2
d. Çocuk, bağımlı eş ya da başka bir yetişkin gibi başkasının bakımı	1	2

İŞLE İLGİLİ AKTİVİTELER

10. Son 7 gün boyunca, gönüllü veya ücretli olarak çalıştınız mı ?

[1.] HAYIR [2.] EVET

10a. Gönüllü veya ücretli olarak haftada kaç saat çalıştınız?

_____ SAAT

10b. Aşağıdaki kategorilerden hangisi işiniz ya da gönüllü çalışmanız için gerekli fiziksel aktivite miktarını en iyi tanımlar ?

[1] Çoğunlukla hafif kol hareketleriyle oturma.
[Örnekler: büro memuru, saatçi, oturan montaj hattı işçisi, otobüs şoförü, vb.]

[2] Biraz yürüme ile oturma ya da ayakta durma.
[Örnekler: kasiyer, genel büro memuru, hafif araç ve makina işçisi.]

[3] Genel olarak ağırlığı 20 kilodan az olan eşyaları taşıyarak yürüme.
[Örnekler: postacı, garson, inşaat işçisi, ağır araç ve makina işçisi.]

[4] 20 kilodan fazla olan eşyaları taşımayı gerektiren ağır el işi ve yürüme
[Örnekler: oduncu, taş duvarcısı, çiftlik ya da umumi işçi.]

APPENDIX F: WESTERN ONTARIO AND McMASTER UNIVERSITIES ARTHRITIS INDEX (WOMAC)

Her aktivite için tek bir numarayı işaretleyin.		Ağrı Yok	Hafif Ağrı	Orta Derecede Ağrı	Şiddetli Ağrı	Çok Şiddetli Ağrı
Ağrı	Düz zeminde yürümekle ağrı	❑0	❑1	❑2	❑3	❑4
	Merdiven inip çıkmakla ağrı	❑0	❑1	❑2	❑3	❑4
	Gece yatakta ağrı	❑0	❑1	❑2	❑3	❑4
	Otumak veya uzanmakla ağrı	❑0	❑1	❑2	❑3	❑4
	Ayakta durmakla ağrı	❑0	❑1	❑2	❑3	❑4

Her aktivite için tek bir numarayı işaretleyin.		Sertlik Yok	Hafif Sertlik	Orta Derecede Sertlik	Şiddetli Sertlik	Çok Şiddetli Sertlik
Sertlik	Sabah ilk yürüme sırasında sertlik	❑0	❑1	❑2	❑3	❑4
	Gün içinde oturma, uzanma, istirahat sonrası sertlik	❑0	❑1	❑2	❑3	❑4

Her aktivite için tek bir numarayı işaretleyin.		Zorluk Yok	Hafif Zorluk	Orta Derecede Zor	Epey Zor	Çok Çok Zor
Fiziksel Fonksiyon	Merdiven inme	❑0	❑1	❑2	❑3	❑4
	Merdiven çıkma	❑0	❑1	❑2	❑3	❑4
	Otururken ayağa kalkma	❑0	❑1	❑2	❑3	❑4
	Ayakta durma	❑0	❑1	❑2	❑3	❑4
	Yere eğilme (çömelme)	❑0	❑1	❑2	❑3	❑4
	Düz zemin üzerinde yürüme	❑0	❑1	❑2	❑3	❑4
	Arabaya inme-binme	❑0	❑1	❑2	❑3	❑4
	Alışveriş yapma	❑0	❑1	❑2	❑3	❑4
	Çorap giyme	❑0	❑1	❑2	❑3	❑4
	Çorap çıkartma	❑0	❑1	❑2	❑3	❑4
	Yataktan kalkma	❑0	❑1	❑2	❑3	❑4
	Yatakta uzanma	❑0	❑1	❑2	❑3	❑4
	Banyo küvetine girme-çıkma	❑0	❑1	❑2	❑3	❑4
	Otuma	❑0	❑1	❑2	❑3	❑4
	Tuvalete girme-çıkma	❑0	❑1	❑2	❑3	❑4
	Ağır ev işleri	❑0	❑1	❑2	❑3	❑4
	Hafif ev işleri	❑0	❑1	❑2	❑3	❑4

Bellamy N. Osteoarthritis - An evaluative index for clinical trials. MSc Thesis. McMaster University, Hamilton, Canada. 1982

$$Toplam\ Skor = \frac{(Toplam\ Puan \times 100)}{96}$$

Toplam Skor= % .....

APPENDIX G: ÖZGEÇMİŞ

Kişisel Bilgiler

Adı	**Nilay**	**Soyadı**	**ARAL**
Doğum Yeri		**Doğum Tarihi**	
Uyruğu		**TC Kimlik No**	
E-mail		**Tel**	

Öğrenim Durumu

Derece	**Alan**	**Mezun Olduğu Kurumun Adı**	**Mezuniyet Yılı**
Doktora			
Yüksek Lisans	**Fizyoterapi ve Rehabilitasyon**	**Yeditepe Üniversitesi**	**2023**
Lisans	**Fizyoterapi ve Rehabilitasyon**	**Yeditepe Üniversitesi**	**2020**
Lise	**Fen Matematik**	**İstanbul Kadıköy Lisesi**	**2015**

Bildiği Yabancı Dilleri	**Yabancı Dil Sınav Notu (#)**
İngilizce	**C1 seviyesi**

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	**Kurum**	**Süre (Yıl - Yıl)**
Fizyoterapist	**Sante Tıp Merkezi**	**Haziran 2021- Halen**
Fizyoterapist	**Green Diamond**	**Mart 2021-Haziran 2021**

Bilgisayar Bilgisi

Program	**Kullanma becerisi**
Office Programları	**Orta**

***Çok iyi, iyi, orta, zayıf olarak değerlendirin**

APPENDIX H: THESIS CONTROL LIST

Tezi son haline getirip çoğaltmadan önce aşağıdaki kontroller yapılmalıdır

☒ Kapak ve iç kapak sayfalarında YÜKSEK LİSANS veya DOKTORA şeklinde elde edilen unvanlar yazıldı (Kapak sayfasına danışman adı yazılmamalıdır).

☒ Kapak sayfasına mezun olunan PROGRAMIN (Anabilim dalının değil) adı yazıldı.

☒ Tez kapağı sırt kısmına kılavuzda belirtilen şekilde (yazının yönüne dikkat!) ad-soyad, enstitünün adı, program, yıl yazıldı.

☒ Kapakta yalnız tez başlığı 18 punto ve koyu renk, Enstitü ve Anabilim Dalı 14 punto ve diğer yazılar 12 punto ile yazıldı.

☒ Onay sayfası uygun şekilde hazırlandı (kazanılan unvanlar YÜKSEK LİSANS veya DOKTORA olmalıdır), imzalatıldı (Enstitü Müdürü'nün imzası da gereklidir, imzaların aynı renk kalemle atılmasına dikkat edilmelidir).

☒ Çıktılar kaliteli çıktı veren bir bilgisayar kullanılarak, kâğıdın tek yüzüne alındı.

☒ Dizinler kılavuzda belirtildiği gibi sıralandı.

☒ Ön sayfalara i, ii, iii şeklinde Roma rakamları konuldu.

☒ Sayfa numaraları kılavuzda belirtildiği şekilde konuldu.

☒ Sayfa düzeni kılavuzda belirtildiği şekilde yapıldı.

☒ Ana metin Times New Roman yazı tipi ile harf büyüklüğü 12 punto olacak şekilde basıldı.

☒ Dipnot harf büyüklüğü 8-10 punto olacak şekilde basıldı.

☒ Ana metin satır aralığı 1.5 olacak şekilde yazıldı.

☒ Türkçe ve İngilizce özet birbiri ile uyumlu olarak yazıldı.

☒ Türkçe ve İngilizce özete uygun anahtar kelimeler konuldu.

☒ Kısaltma ve semboller uygun şekilde yapıldı.

☒ Kaynaklar listesinde, her kaynağa numara verildi. Kaynak gösterme ilkelerine ve künye kurallarına uygun şekilde yazıldı.

☒ Tezde kullanılan bütün kaynaklar temin edildi.

☒ Ekler uygun başlıklarla, tezdeki sunuş sırasına göre, ayrı sayfalardan başlamak üzere verildi.