Jurnal Kesehatan Manarang

Jurnal Kesehatan Manarang, Volume 10, Nomor 1, April 2024, pp. 35-42
ISSN 2528-5602 (Online), ISSN 2443-3861 (Print)
doi: https://doi.org/10.33490/jkm.v10i1.934

THE EFFECT OF MUSCLE ENERGY TECHNIQUE ON PAIN AND RANGE OF MOTION IN PATIENT WITH KNEE OSTEOARTHRITIS

Dwi Rosella Komalasari ✉, **Tri Mukti Handayani**

Department of Physiotherapy Faculty of Health Science Muhammadiyah University of Surakarta

ARTICLE INFO

Article history

Submitted : 2024-2-27
Revised : 2024-3-25
Accepted : 2024-3-30

Keywords:

Muscle Energi Technique;
Pain;
Range of motion;
Knee Osteoarthritis

ABSTRACT

Osteoarthritis (OA) is a progressive degenerative joint disorder characterised by pain, stiffness, and limited range of motion (ROM). According to the World *Health Organization* (WHO), OA is one of the main causes of decreased quality of human life worldwide. *Muscle Energy Technique* (MET) is a treatment used to treat OA. This study aimed to determine the effect of MET on pain and ROM in knee OA patients. This research used a type of pra experimental research. The research group consisted of 15 patients with knee OA by purposive sampling who received the MET technique once a week for 4 weeks. Pain was measured by the Numeric Rating Scale (NRS), while a goniometer was used for evaluating the ROM of knee flexion and extension. There was a significant decrease in the average pain score before (4.7/10) and after (3.4/10) MET administration. LGS knee flexion increased by 7 degrees, while LGS knee extension decreased by 1.4 degrees. Statistically, MET positively reduces pain and increases ROM in knee OA ($p<0.05$). MET is one of the recommended techniques for health workers and physiotherapists in particular, in the management of reducing pain and increasing ROM for patients with knee OA.

Kata Kunci:

Muscle Energy Technique;
Nyeri;
Lingkup gerak sendi;
Osteoarthritis lutut

ABSTRAK

Osteoarthritis (OA) merupakan gangguan sendi degeneratif progresif yang ditandai dengan nyeri sendi, kekakuan, dan keterbatasan lingkup gerak sendi. Menurut World Health Organization (WHO), OA menjadi salah satu penyebab utama yang mengakibatkan turunnya kualitas hidup manusia di dunia. Muscle Energy Technique (MET) merupakan penanganan yang digunakan untuk mengatasi OA. Tujuan studi ini untuk mengetahui pengaruh MET terhadap nyeri dan ROM pada pasien OA lutut. Penelitian ini menggunakan jenis penelitian pra eksperimental. Kelompok penelitian terdiri dari 15 pasien OA lutut secara purposive sampling yang mendapatkan latihan MET satu kali perminggu selama 4 minggu. Nyeri diukur dengan Numeric Rating Scale (NRS), sedangkan goniometer digunakan untuk mengevaluasi ROM fleksi dan ekstensi lutut.

Terdapat penurunan nilai rata-rata nyeri yang signifikan dari sebelum (4.7/10) dan sesudah (3.4/10) pemberian MET. LGS fleksi lutut mengalami peningkatan 7 derajad, sedangkan LGS ekstensi lutut mengalami penurunan 1,4 derajad. Secara statistik MET memberikan efek positif dalam mengurangi nyeri dan meningkatkan ROM pada pasien OA lutut ($p<0.05$). MET merupakan salah satu Teknik yang direkomendasikan untuk tenaga kesehatan khususnya fisioterapi, dalam penatalaksanaan penurunan nyeri dan peningkatan ROM pada pasien OA lutut.

✉ ***Corresponding Author:***

Dwi Rosella Komalasari
Department of Physiotherapy, Health Science Faculty
Universitas Muhammadiyah Surakarta
Email: drks133@ums.ac.id

INTRODUCTION

World Health Organization (WHO) found that a common joint disease called osteoarthritis (OA) is a big reason why people around the world have a lower quality of life. Osteoarthritis is a long-term condition that gets worse over time and causes pain, stiffness, and difficulty moving the joints. These problems can make it hard for people to do everyday activities, which can lower their quality of life. OA has a prevalence of 365 million, the knee is the most frequently affected joint, followed by the hip and the hand (Nelson et al., 2014).

Osteoarthritis (OA) is a common form of arthritis that can affect various joints in the body, including the knees, hips, hands, and spine. Among these, knee osteoarthritis is one of the most prevalent forms. While it's challenging to provide an exact percentage of knee osteoarthritis compared to other types of OA due to variations in study populations and methodologies, knee OA is generally considered to be among the most common types of osteoarthritis (Allen et al., 2022)

While knee osteoarthritis may be more prevalent than other types of OA in certain populations or age groups, the overall burden of OA varies depending on factors such as age, gender, genetics, and lifestyle factors. Additionally, many individuals may experience osteoarthritis in multiple joints simultaneously, further complicating the assessment of prevalence rates by joint location. It's important to note that osteoarthritis can have a significant impact on individuals' quality of life regardless of the affected joint, and appropriate management strategies are essential for improving symptoms and maintaining function (Hamood et al., 2021)

The causes of OA are still not clearly understood, several factors contribute to its development Osteoarthritis (OA) is a complex condition with multifactorial causes. These factors can be categorized into biomechanical, genetic, and environmental influences. The aging process and history of trauma are the main risk factors that can identify the development of OA and indicated with other factors such biomechanical factors that included joint overuse or injury and mechanical stress, genetics, obesity, inflammation, gender, and hormones (Ghosh, 2022)

Generally, OA attacks elderly people over 60 years of age. Aging is a significant risk factor for osteoarthritis. As people age, the cartilage in their joints may naturally wear down and become less resilient, making them more susceptible to OA (Gema Jimenez, Jesus Cobo-Molinos, Cristina Antich, 2018). Excess body weight is strongly associated with osteoarthritis, particularly in weight-bearing joints such as the knees and hips. Obesity increases mechanical stress on joints, accelerates cartilage degeneration, and promotes inflammation (Shumnalieva et al., 2023). Chronic inflammation in the joint, whether due to other forms of arthritis or systemic inflammatory conditions, can contribute to the development or progression of OA (Chow & Chin, 2020). In addition, poor physical activity or lack of physical activity can contribute to the progression of OA. Lack of physical activity can lead to muscle weakness, particularly around the joints affected by OA. Weak muscles may provide inadequate support to the joints, leading to increased stress and wear on the joint structures (Patterson, Girdwood, west, bruderQiestad, carsten, 2023). Besides that can increase joint stiffness, decrease joint lubrication, poor joint stability that those impact to rlow QoL (Uritani, Koda, Yasuura, 2022).

The management of OA typically involves a combination of non-pharmacological and pharmacological treatments, as well as lifestyle modifications. The goal of treatment is to alleviate pain, improve joint function, and enhance overall QoL (Grässel & Muschter, 2020). Pharmacological treatments for knee osteoarthritis (OA) aim to alleviate pain, reduce inflammation, and improve function. Commonly, the doctor gives analgesics, topical medication corticosteroid injections, disease-modifying osteoarthritis drugs, opioids and supplements. Opioids may be prescribed for individuals with severe knee OA pain who have not responded adequately to other treatments. However, their use is generally limited due to the risk of dependence, tolerance, and other adverse effects (Paul et al., 2021)

Non-pharmacological treatments play a crucial role in the management of OA and can significantly improve symptoms and quality of life for affected individuals. Such as exercise, manual therapy, weight management, physical therapy, joint protection technique, education and self-management, hot and cold therapy, assisted devices, mind body technique, nutritional supplements and acupuncture. Muscle Energy Technique (MET) is a manual therapy technique commonly used by physical therapists, osteopaths, chiropractors, and other healthcare professionals to address musculoskeletal dysfunctions, improve joint mobility, and alleviate pain. MET is based on principles of osteopathic medicine and involves active participation from the patient (Chaitow, 2023). MET can be

used to address a variety of musculoskeletal conditions, including joint restrictions, muscle imbalances, postural dysfunctions, and soft tissue injuries. It aims to restore normal biomechanical function, improve joint mobility, and alleviate pain by activating the body's natural healing mechanisms.

Studies suggest MET is a more effective approach for various goals. These include improving muscle strength, increasing lymph and vein blood flow, and expanding joint range of motion. MET involves a combined technique of pressing and stretching muscles, leading to biomechanical and neurophysiological changes that ultimately enhance muscle flexibility and joint mobility (Krzysztofik et al., 2019). Further research by Smith & Fryer confirms MET's effectiveness in improving muscle strength and flexibility. Therefore, they recommend using MET as a treatment for knee OA.

Unfortunately, the evidence regarding the effectiveness of MET specifically for pain management in knee OA is limited and mixed. While MET is a commonly used manual therapy technique, research specifically focusing on its efficacy for knee OA pain is not as extensive as for other interventions. There are relatively few studies specifically investigating the effects of MET on knee OA pain and range of motion. Most of the research on MET focuses on its use in various musculoskeletal conditions rather than specifically on knee OA (Faqih et al., 2019). The few studies that have investigated MET for knee OA pain have reported mixed results. Some studies have suggested that MET may be beneficial for reducing pain and improving function in individuals with knee OA, while others have found no significant effects compared to other interventions or control groups (Tsokanos et al., 2021). The effectiveness of MET for ROM in knee OA may be influenced by various factors, including patient characteristics, severity of OA, concurrent treatments, and individual response to therapy. These factors can make it challenging to isolate the specific effects of MET on ROM in knee OA (Dantas, Salvini, 2021). Therefore, this study aimed to determine the effect of MET on pain and range of motion in patients with knee OA.

METHOD

This research was approved form research ethics committee of the Health Research Ethics Committee, Medical Faculty of Muhammadiyah University of Surakarta with number 4538/B.1/KEPK-FKUMS/X/2022. This type of research is a pra-experimental study. The research was conducted at the Physiotherapy devision at PKU Muhammadiyah Hospital, Sukoharjo, Central Java. There were 15 patients met the inclusion criteria in this study who were taken using purposive sampling, including (1) aged 55 – 80 years, (2) diagnosed with unilateral knee OA, (3) OA grade ≥ 2 based on the Kellgren and Lawrence classification, (4) knee pain score of at least 3 measured by the Numeric Rating Scale, (5) walking without assisted devices, and (6) can communicate well. Meanwhile, patients excluded from this study if; (1) had a history of surgery on the lower extremities, (2) had neurological diseases (stroke, Parkinson's, cerebral ataxia, (3) hypersensitivity around the knees, and (4) complained of persistent lower back pain that associated with knee pain. MET were applied once a week for 4 weeks. Pain and LGS were evaluated before and after therapy. Pain was evaluated using NRS with a score of zero (no pain) and a score of 10 (unbearable pain). Meanwhile, for range of motion was measured by a goniometer for flexion and extension of the knee joint.

The MET technique given is a manual post isometric relaxation (PIR) therapy technique on the Quadriceps Femoris and Hamstring muscles. The PIR technique aims to mobilize the knee joint, stretch the quadriceps and hamstring muscles, reduce pain and improve circulation and lymphatic flow. Based on a book from Leon Chaitow entitled Muscle Energy Technique 3rd ed. stretching the hamstring muscles with the knee bent (flexed) to the limit of resistance (pain limit) that felt by the patient, then asking the patient to make an active motion to straighten the lower leg antagonistically muscle to the hamstring for 10 seconds. Return to a relaxed position and stretch towards the trunk (above) and hold for 30 seconds. Meanwhile, stretch the quadrieceps muscles, position the patient on his stomach (prone lying), then bend (flexed) the patient's knees passively to the pain threshold. Thus, the patient was asked to push the knees down against the resistance of the therapist's hands. Hold for 10 seconds and then stretch for 30 seconds. Stretching the quadriceps and hamstring muscles was done in 2 sets, 3 repetitions per set, and for each repetition there was a rest period of 7 seconds. The time interval between sets is 1-2 minutes depending on the patient's pain tolerance.

The Wilcoxon test was used in to determine the effect of MET on pain and LGS in knee OA patients. This research data description presents minimum, maximum, average (mean) and standard deviation (sd) to provide an overview and explain the characteristics of each variable.

RESULTS

Table 1. Characteristic of respondents (n=15)

Variable	N (%)	Minimum	Maksimum	Mean ± SD
Age (years)		56	78	63.6 ± 5.3
56-65	12 (80%)			
>65	3 (20%)			
Gender				
Male	2 (13.3%)			
Female	13 (86.7%)			
Side of OA				
Right	6 (40%)			
Left	9 (60%)			
Grade of OA				
Grade 2	4 (26.7%)			
Grade 3	7 (46.7%)			
Grade 4	4 (26.7%)			
Duration of OA (month)		1	39	13.8 ± 13.1
1-12	9 (60%)			
13-24	3 (20%)			
≥25	3 (20%)			
Pain (NRS)				
Pre		3	9	4.7 ± 2.05
Post		1	8	3.4 ± 2.03
ROM of knee flexion		95	125	112.3 ± 8.6
Pre		105	130	119.3 ±7.2
Post				
ROM of knee extension		0	5	1.7 ± 2.4
Pre		0	5	0.3 ± 1.29
Post				

Table 1 shows that the average of age was over 60 years andd female was dominating in this study. The left side of knee OA presented by 60%, it was higher than right side. Grade of knee OA by Kellgren and Lawrance criterias shown that mostly the patients had grade 3. While, grade 2 and 4 had the same amount. Duration of OA describes a high number for a duration of 1-12 months. There was reduction on pain scale between before and after MET treatment, 4.7 and 3.4 respectively. Likewise, in the range of motion, where the ability to flex the knee increases from 95 degrees to 105 degrees. While, the range of motion of the knee extension joint does not change in degree after MET application for 1 month.

Table 2 Wilcoxon test of effect of MET on pain and range of motion of the knee joint in knee OA

Variable	Mean pre	Mean post	*p*-value
Pain	4.7	3.4	0.001
ROM			
Knee flexion pre-post	112.3	119.3	0.001
Knee extension	1.7	0.3	0.046

Table 2 describes MET gives possitive effect to reduce pain and ROM in patients with knee OA ($p<0.05$).

DISCUSSIONS

Table 1 shows that female is dominating in this study. Osteoarthritis affects both genders, it can manifest and worsen differently in men and women. This variation is likely due to several factors, including hormonal imbalances, anatomical distinctions, and lifestyle choices. For instance, osteoarthritis seems to be more prevalent in women's knees and hands (Peshkova et al., 2022). Hormones influence the development of OA. Estrogen, found more abundantly in women, helps keep cartilage healthy. When estrogen levels fluctuate, like during menopause, it can contribute to the onset of OA (Castañeda & Vicente-Rabaneda, 2023). In addition, men and women's bodies are built differently, affecting how their joints move and function. For instance, women tend to have wider hips, which can shift how the knees align and distribute weight. This difference may make them more susceptible to OA in the knees (Diekhoff et al., 2019).

Furthermore, activities that place repetitive stress on the joints, such as certain types of exercise or occupations, can contribute to the development of OA. Women may engage in activities that put more stress on certain joints, increasing their risk of OA (Buehler et al., 2021). As well, obesity is a significant risk factor for OA, particularly in weight-bearing joints like the knees. Women are more likely than men to be obese, which can contribute to the higher prevalence of OA in women (Bliddal et al., 2014).

Actually, dominant side of knee OA is not common only one side. But, for most people, the right side of the body is dominant. This means that it's often subjected to more repetitive movements, strain, and wear and tear over time, potentially leading to a higher incidence of OA. Women generally have different joint structures and biomechanics compared to men, which can impact the development of osteoarthritis (OA). For instance, women typically have wider hips, altering the alignment and loading of the knees and potentially increasing the risk of OA in that joint. Activities that place repetitive stress on the joints, such as certain exercises or occupations, can contribute to OA development through joint loading. Women may engage in activities that stress specific joints more, thus heightening their OA risk (Buehler et al., 2021). Additionally, obesity, a significant risk factor for OA, particularly affects weight-bearing joints like the knees, and women are more prone to obesity than men, contributing to a higher prevalence of OA in women (Shumnalieva et al., 2023). Genetics also influence OA development, with certain genetic factors predisposing individuals to the condition, and there may be gender-based genetic differences affecting OA risk. Furthermore, socioeconomic factors like access to healthcare, occupational hazards, and lifestyle choices can vary between men and women and impact OA risk accordingly (Warner & Valdes, 2016).

While the severity of osteoarthritis (OA) often increases over time (indicated by a positive correlation with duration), this isn't always a simple cause-and-effect relationship. Several factors can influence this connection, including how the disease progresses in each person, the treatments they receive, and their lifestyle choices (M. H. M. Yunus et al., 2020). The progression of osteoarthritis (OA) often occurs gradually over time, with joint damage worsening as the disease advances, leading to higher grades of OA in individuals with longer durations of the condition compared to those with shorter durations. Additionally, the effectiveness of treatment interventions can influence the duration of OA, as early diagnosis and appropriate management strategies can slow disease progression and potentially prevent it from reaching higher grades (U. Yunus et al., 2022). However, untreated or undertreated OA may advance more rapidly to higher grades over time. Moreover, there is significant variability among individuals in how OA progresses, with some experiencing relatively mild symptoms despite a long duration of the condition, while others may undergo rapid deterioration in joint health. Various factors such as genetics, lifestyle, comorbidities, and treatment adherence contribute to this variability. Furthermore, accurately determining the duration of OA can be challenging, particularly if symptoms were mild or intermittent in the early stages, potentially impacting the clarity of the relationship between OA grade and duration in certain cases (Chen et al., 2017)

In table 1 shows that MET was able reduce pain and increase ROM and also the analysis shows significant effect of MET on pain and ROM in patient with OA knee (table 2). Muscle Energy Technique (MET) offers multifaceted benefits for pain management and rehabilitation. Initially, it facilitates muscle relaxation by employing reciprocal inhibition and autogenic inhibition, inducing a reduction in muscle tension and promoting pain relief (Chen et al., 2017). Additionally, MET targets improved joint

mobility by addressing soft tissue restrictions and encouraging active movements, thus mitigating pain associated with limited joint motion, such as in osteoarthritis (OA). Furthermore, MET may modulate pain perception through mechanisms like stimulating mechanoreceptors and proprioceptors, potentially alleviating discomfort by affecting pain signals to the central nervous system and promoting the release of endorphins. Moreover, MET aims to normalize muscle function by rectifying imbalances and enhancing coordination, contributing to pain reduction by restoring optimal movement patterns (A et al., 2023). Moreover, its rhythmic contractions and relaxations enhance blood flow, facilitating tissue healing and inflammation reduction. Finally, the therapeutic interaction during MET sessions fosters psychological well-being, including relaxation and decreased anxiety, which complements pain relief efforts. Together, these aspects highlight the comprehensive approach of MET in addressing pain and enhancing overall rehabilitation outcomes (Tu, 2023).

Through MET, patients actively participate in specific muscle contractions against controlled resistance provided by the therapist. MET assists in identifying restricted areas of motion by pinpointing specific muscles or joints that require attention. By assessing these limitations, therapists can tailor the treatment to address individual needs effectively (Tu, 2023). Besides that, MET employs contract-relax techniques or post-isometric relaxation (PIR) methods, where patients contract targeted muscles isometrically against resistance before relaxing. This process helps alleviate muscle tension and encourages the elongation of tight muscles, consequently increasing joint mobility (Dicks, 2022). Moreover, MET contributes to neuromuscular re-education by promoting proprioceptive awareness and improving muscle coordination. Through repetitive contractions and relaxations, patients learn to engage muscles more efficiently, facilitating smoother and more controlled movements (Mahendra et al., 2022). Additionally, MET sessions often incorporate passive stretching administered by the therapist after active muscle contractions. This stretching phase further extends the range of motion by capitalizing on the increased muscle flexibility achieved during the contract-relax phase (Talley, 2020).

Furthermore, MET interventions are typically supplemented with personalized home exercise programs aimed at maintaining and enhancing the gains achieved during therapy sessions. These programs empower patients to continue their progress independently and reinforce the improvements in joint mobility over time (Argent et al., 2018). Overall, the comprehensive approach of MET, encompassing muscle relaxation, neuromuscular re-education, passive stretching, and patient empowerment through home exercises, collectively contributes to significant enhancements in joint range of motion and functional mobility.

CONCLUSIONS AND SUGGESTIONS

Based on the research results, it was found that MET was able to reduce the pain complained of by patients, especially when carrying out daily activities. And also, MET is able to increase the ROM of knee joint, for flexion and extension motion. Overall, while more research is needed to fully understand the effectiveness of MET specifically for pain and ROM in OA, preliminary evidence suggests that MET can be a valuable component of OA management, particularly when integrated into a comprehensive rehabilitation program tailored to the individual needs of patients with OA. Future researchers are encouraged to consider the respondent's focus during measurements and to offer explanations using clear language, facilitating accurate assessments of the conditions experienced during data collection. Additionally, MET requires a certain level of patient cooperation and understanding of the technique, which may not always be achievable in all clinical settings or with all patient populations.

REFERENCES

A, C., U, D. M., & A, C. (2023). Pain Relief Effect of Crackdol® Fast Foam in Osteoarticular Disorders. *Journal of Clinical Studies & Medical Case Reports*, *10*(5), 1–4. https://doi.org/10.24966/csmc-8801/1000193

Allen, K. D., Thoma, L. M., & Golightly, Y. M. (2022). Epidemiology of osteoarthritis. *Osteoarthritis and Cartilage*, *30*(2), 184–195. https://doi.org/10.1016/j.joca.2021.04.020

Argent, R., Daly, A., & Caulfield, B. (2018). Patient involvement with home-based exercise programs: Can connected health interventions influence adherence? *JMIR MHealth and UHealth*, *6*(3). https://doi.org/10.2196/mhealth.8518

Bliddal, H., Leeds, A. R., & Christensen, R. (2014). Osteoarthritis, obesity and weight loss: Evidence, hypotheses and horizons - a scoping review. *Obesity Reviews*, *15*(7), 578–586. https://doi.org/10.1111/obr.12173

Buehler, C., Koller, W., De Comtes, F., & Kainz, H. (2021). Quantifying Muscle Forces and Joint Loading During Hip Exercises Performed With and Without an Elastic Resistance Band. *Frontiers in Sports and Active Living*, *3*(August), 1–13. https://doi.org/10.3389/fspor.2021.695383

Castañeda, S., & Vicente-Rabaneda, E. F. (2023). Disentangling the molecular interplays between subchondral bone and articular cartilage in estrogen deficiency-induced osteoarthritis. *Osteoarthritis and Cartilage*, *31*(1), 6–8. https://doi.org/10.1016/j.joca.2022.09.006

Chaitow, F. (2023). *Evidence-Informed Muscle Energy Techniques in The Biopsychosocial Framework*. https://books.google.co.id/books?hl=id&lr=&id=bke6EAAAQBAJ&oi=fnd&pg=PA1&dq=Chaitow+%26+Fritz,+2023&ots=URaLoK5-IV&sig=m-lF-8tlyaQqL6HeUEUhirLpii8&redir_esc=y#v=onepage&q=Chaitow %26 Fritz%2C 2023&f=false

Chen, D., Shen, J., Zhao, W., Wang, T., Han, L., Hamilton, J. L., & Im, H. J. (2017). Osteoarthritis: Toward a comprehensive understanding of pathological mechanism. *Bone Research*, *5*(September 2016). https://doi.org/10.1038/boneres.2016.44

Chow, Y. Y., & Chin, K. Y. (2020). The Role of Inflammation in the Pathogenesis of Osteoarthritis. *Mediators of Inflammation*, *2020*. https://doi.org/10.1155/2020/8293921

Dantas, Salvini, A. (2021). Knee Osteoarthritis: Key Treatments and Implications for Physical Therapy. *Brazilian Journal of Physical Therapy*, *25*(2), 135–146. https://www.sciencedirect.com/science/article/abs/pii/S1413355520302434

Dicks. (2022). Chondrogenic Differentiation of Human-Induced Pluripotent Stem Cells. *Cartilage Tissue Engineering*, 87–114. https://link.springer.com/protocol/10.1007/978-1-0716-2839-3_8

Diekhoff, D. D., Diekhoff, G. M., & Vandehey, M. A. (2019). A comparison of men's and women's perceptions of the female body using a multidimensional scaling analysis of naturalistic stimuli. *Health Psychology Open*, *6*(1). https://doi.org/10.1177/2055102919854665

Faqih, A. I., Bedekar, N., Shyam, A., & Sancheti, P. (2019). Effects of muscle energy technique on pain, range of motion and function in patients with post-surgical elbow stiffness: A randomized controlled trial. *Hong Kong Physiotherapy Journal*, *39*(1), 25–33. https://doi.org/10.1142/S1013702519500033

Gema Jimenez, Jesus Cobo-Molinos, Cristina Antich, E. L.-R. (2018). Osteoarthritis: Trauma Vs Disease. *Osteochondral Tissue Engineering*, 63–83.

Ghosh, P. (2022). Osteoarthritis, genetic and molecular mechanisms. *Biogerontology*, *3*, 85–88.

Grässel, S., & Muschter, D. (2020). Recent advances in the treatment of osteoarthritis. *F1000Research*, *9*(May). https://doi.org/10.12688/f1000research.22115.1

Hamood, R., Tirosh, M., Fallach, N., Chodick, G., Eisenberg, E., & Lubovsky, O. (2021). *Prevalence and Incidence of Osteoarthritis : A Population-Based Retrospective Cohort Study*.

Krzysztofik, M., Wilk, M., Wojdała, G., & Gołaś, A. (2019). Maximizing muscle hypertrophy: A systematic review of advanced resistance training techniques and methods. *International Journal of Environmental Research and Public Health*, *16*(24). https://doi.org/10.3390/ijerph16244897

Mahendra, N. Y., Putra, D. P., Akbar, I., Putra, R. U., Prakoso, A. T., Yanis, M., Chandra, H., Syahrom, A., Amrullah, M. I., Jamari, J., & Basri, H. (2022). Narrative Review of Subchondral Bone Morphology on Cartilage Damage (Osteoarthritis). *Proceedings of the 5th FIRST T1 T2 2021 International Conference (FIRST-T1-T2 2021)*, *9*, 77–82. https://doi.org/10.2991/ahe.k.220205.014

Nelson, A. E., Allen, K. D., Golightly, Y. M., Goode, A. P., & Jordan, J. M. (2014). A systematic review of recommendations and guidelines for the management of osteoarthritis: The Chronic Osteoarthritis Management Initiative of the U.S. Bone and Joint Initiative. *Seminars in Arthritis and Rheumatism*, *43*(6), 701–712. https://doi.org/10.1016/j.semarthrit.2013.11.012

Patterson, Girdwood, west, bruderQiestad, carsten, C. (2023). Muscle Strength and Osteoarthritis of the Knee: a Systematic Review and Meta-Analysis of Longitudinal Studies. *Skletal Radiology*, *52*, 2085–2097. https://link.springer.com/article/10.1007/s00256-022-04266-4

Paul, A. K., Smith, C. M., Rahmatullah, M., Nissapatorn, V., Wilairatana, P., Spetea, M., Gueven, N., & Dietis, N. (2021). Opioid analgesia and opioid-induced adverse effects: A review. *Pharmaceuticals*, *14*(11), 1–22. https://doi.org/10.3390/ph14111091

Peshkova, M., Lychagin, A., Lipina, M., Di Matteo, B., Anzillotti, G., Ronzoni, F., Kosheleva, N., Shpichka, A., Royuk, V., Fomin, V., Kalinsky, E., Timashev, P., & Kon, E. (2022). Gender-Related Aspects in Osteoarthritis Development and Progression: A Review. *International Journal of Molecular Sciences*, *23*(5). https://doi.org/10.3390/ijms23052767

Shumnalieva, R., Kotov, G., & Monov, S. (2023). *Obesity-Related Knee Osteoarthritis — Current Concepts*.

Talley, G. (2020). Osteopathic Manipulative Treatment: Muscle Energy Procedure With Post-Isometric Relaxation - Thoracic Vertebrae. *Europe PMC*. https://europepmc.org/article/nbk/nbk560895#free-full-text

Tsokanos, A., Livieratou, E., Billis, E., Tsekoura, M., Tatsios, P., Tsepis, E., & Fousekis, K. (2021). The efficacy of manual therapy in patients with knee osteoarthritis: A systematic review. *Medicina (Lithuania)*, *57*(7), 1–12. https://doi.org/10.3390/medicina57070696

Tu, L. (2023). Orientin inhibits inflammation in chondrocytes and attenuates osteoarthritis through Nrf2/NF-κB and SIRT6/NF-κB pathway. *Journal of Orthopaedic Research*. https://onlinelibrary.wiley.com/doi/abs/10.1002/jor.25573

Uritani, Koda, Yasuura, K. (2022). Factors Associated With Subjective Knee joint Stiffness in People With Knee Osteoarthritis: A Systematic Review. *International Journal of Rheumatic Diseases*. https://doi.org/doi.org/10.1111/1756-185X.14536

Warner, S. C., & Valdes, A. M. (2016). The genetics of osteoarthritis: A review. *Journal of Functional Morphology and Kinesiology*, *1*(1), 140–153. https://doi.org/10.3390/jfmk1010140

Yunus, M. H. M., Nordin, A., & Kamal, H. (2020). Pathophysiological perspective of osteoarthritis. *Medicina (Lithuania)*, *56*(11), 1–13. https://doi.org/10.3390/medicina56110614

Yunus, U., Amin, J., Sharif, M., Yasmin, M., Kadry, S., & Krishnamoorthy, S. (2022). *Recognition of Knee Osteoarthritis (KOA) Using YOLOv2 and Classification Based on Convolutional Neural Network*. https://www.mdpi.com/2075-1729/12/8/1126