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Research

Comparative Efficacy of Interferential Therapy and Ultrasound Combined with Knee Exercises vs. TENS with Knee Exercises in Grade 3–4 Knee Osteoarthritis: A Six-Month Randomized Controlled Trial

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Abstract

Background: Severe knee osteoarthritis (OA), classified as Kellgren-Lawrence (KL) grades 3-4, significantly impairs mobility and quality of life. Non-pharmacological interventions, including electrotherapy modalities, are increasingly utilized to manage symptoms. This study evaluates the comparative efficacy of interferential therapy (IFT) combined with ultrasound (US) and knee exercises versus transcutaneous electrical nerve stimulation (TENS) with knee exercises in patients with advanced knee OA.

Methods: A prospective, single-blind, randomized controlled trial was conducted with 50 participants diagnosed with KL grade 3–4 knee OA. Participants were randomized into two groups: Group 1 received IFT and US combined with knee exercises, while Group 2 received TENS with knee exercises. Outcomes assessed at baseline, 3 months, and 6 months included pain (Visual Analog Scale, VAS), function (Western Ontario and McMaster Universities Osteoarthritis Index, WOMAC), knee range of motion (ROM), and quality of life (Short Form-36, SF-36).

Results: Group 1 demonstrated statistically significant improvements in WOMAC scores ($\Delta = 15.2$, $p < 0.001$) and VAS scores ($\Delta = 3.1$, $p = 0.002$) compared to Group 2 at 6 months. Additionally, ROM and SF-36 physical component scores favored Group 1 ($p < 0.05$).

Conclusion: The combination of IFT and US with knee exercises significantly outperforms TENS with exercises in managing severe knee OA, supporting their integration into rehabilitation protocols.

Keywords: Knee Osteoarthritis, Interferential Therapy, Therapeutic Ultrasound, Transcutaneous Electrical Nerve Stimulation, TENS, Physiotherapy, Randomized Controlled Trial, Pain Management, Range of Motion, WOMAC, VAS, Non-Pharmacological Treatment.

INTRODUCTION

Knee osteoarthritis (OA) is a prevalent degenerative joint disease characterized by the progressive deterioration of articular cartilage, subchondral bone remodeling, and synovial inflammation. It is a leading cause of disability among the elderly, with a significant impact on mobility and quality of life. The Kellgren-Lawrence (KL) grading system is commonly used to classify the severity of OA, with grades 3 and 4 indicating moderate to severe disease characterized by joint space narrowing, osteophyte formation, and significant functional impairment [1]. Luyten et al. explored the aging-related mechanisms contributing to knee osteoarthritis and the challenges of managing OA in older populations, relevant to the study's focus on adults aged 40-75 [2].

Management of knee OA involves a combination of pharmacological and non-pharmacological interventions. While pharmacological treatments provide symptomatic relief, they may be associated with adverse effects, especially with long-term use. Non-pharmacological approaches, including physical therapy and electrotherapy modalities, have gained prominence due to their safety profiles and potential to improve function and reduce pain.

Zeng et al evaluated various non-invasive treatments, including physical therapy, which helps contextualize the importance of electrotherapy and exercise in knee OA management [3]. Electrotherapy modalities such as interferential therapy (IFT), ultrasound (US), and transcutaneous electrical nerve stimulation (TENS) are commonly employed in physical therapy settings. IFT delivers low-frequency electrical currents to stimulate deep tissues, potentially reducing pain and promoting healing. US therapy uses high-frequency sound waves to generate deep tissue heating, enhancing blood flow and tissue extensibility. TENS applies electrical stimulation to modulate pain perception through the activation of endogenous analgesic mechanisms. Hunter and Bierma-Zeinstra done a thorough examination of the epidemiology and management strategies for osteoarthritis, highlighting the necessity of non-pharmacological treatments, such as those tested in this study [4].

Despite their widespread use, the comparative efficacy of these modalities, particularly in combination with exercise therapy, remains underexplored in patients with advanced knee OA. This study aims to compare the effectiveness of IFT and US combined with knee exercises versus TENS with knee exercises over a 6-month period in individuals with KL grade 3–4 knee OA.

METHODS

Study Design

A prospective, single-blind, randomized controlled trial was conducted to assess the comparative efficacy of two electrotherapy modalities combined with exercise therapy in patients with advanced knee OA. The study was approved by the Institutional Ethics Committee (IRB No. XYZ) and registered at ClinicalTrials.gov (NCT123456).

Participants

Inclusion Criteria

The inclusion criteria for this study comprised adults aged between 40 and 75 years who were clinically and radiographically diagnosed with grade 3 or grade 4 knee osteoarthritis (OA) according to the Kellgren-Lawrence (KL) classification system. These participants were required to present with chronic knee pain that had persisted continuously for a minimum duration of six months, ensuring the selection of individuals with advanced and sustained symptomatic OA for evaluating the long-term efficacy of the therapeutic interventions under investigation.

Exclusion Criteria

The exclusion criteria for the study included individuals with a prior history of knee surgery, as surgical interventions could confound the outcomes related to joint function and pain relief. Participants diagnosed with inflammatory arthritis or other systemic rheumatic conditions were also excluded to ensure the study focused specifically on degenerative knee osteoarthritis. Additionally, individuals with contraindications to electrotherapy

such as those with implanted pacemakers or the presence of skin lesions at electrode application sites were not eligible to participate, in order to ensure patient safety and the integrity of the intervention [5].

Sample Size

A total of 50 participants were enrolled, with 25 individuals randomized to each group. Sample size calculation was performed using G*Power software, considering an alpha level of 0.05, power of 0.80, and an effect size of 0.8, indicating a large effect.

Randomization and Blinding

Participants were randomized into two groups using a computer-generated randomization sequence. Allocation concealment was ensured using sealed opaque envelopes. Outcome assessors were blinded to group assignments to minimize assessment bias.

Interventions

Participants in Group 1 received a combination of Interferential Therapy (IFT), Ultrasound Therapy (US), and supervised exercise therapy [6]. For IFT, four electrodes were strategically positioned around the affected knee joint to deliver medium-frequency electrical currents ranging from 80 to 150 Hz, with each session lasting 20 minutes [7]. This modality aimed to alleviate pain and stimulate deeper tissues without causing discomfort. Ultrasound therapy was administered using a 1 MHz frequency at an intensity of 1.5 W/cm² in pulsed mode with a 20% duty cycle, applied for 10 minutes per session, targeting soft tissue healing and inflammation reduction. In addition to electrotherapy, participants underwent structured and supervised exercise therapy consisting of quadriceps strengthening and range of motion (ROM) exercises, performed three times per week, designed to improve muscular support, enhance joint mobility, and promote functional recovery.

Participants in Group 2 received Transcutaneous Electrical Nerve Stimulation (TENS) in combination with a structured exercise therapy program [8]. TENS was administered by placing electrodes around the knee joint to deliver low-voltage electrical stimulation at frequencies ranging from 50 to 100 Hz, with each session lasting 30 minutes. This modality aimed to modulate pain perception through the stimulation of sensory nerves, following the gate control theory of pain. Alongside TENS, participants engaged in the same exercise regimen as Group 1, consisting of supervised quadriceps strengthening and range of motion (ROM) exercises conducted three times per week. These exercises were designed to enhance joint function, increase mobility, and improve muscular support around the knee.

Outcome Measures

The primary outcomes of the study focused on assessing pain and functional status in individuals with knee osteoarthritis. Pain was evaluated using the Visual Analog Scale (VAS), which ranges from 0 (no pain) to 10 (worst imaginable pain), providing a subjective measure of pain intensity. Functional status was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), a comprehensive tool that evaluates pain, stiffness, and physical function in individuals with knee OA [9]. The secondary outcomes included the measurement of knee Range of Motion (ROM), which was assessed using a goniometer to determine the flexion and extension capabilities of the knee joint. Additionally, the Short Form-36 (SF-36) questionnaire was used to assess the quality of life of participants, focusing on the physical component summary (PCS) score, which reflects overall physical health and functionality. All assessments were conducted at baseline, 3 months, and 6 months to track changes over the duration of the study.

Statistical Analysis

Data analysis was performed using SPSS version 28.0. Normality of data distribution was assessed using the Shapiro-Wilk test. A mixed-model ANOVA was employed to evaluate time × group interactions for outcome measures. Post hoc analyses with Bonferroni correction were applied for multiple comparisons. An intention-to-treat approach was adopted, with the last observation carried forward (LOCF) method used for missing data. Effect sizes were calculated using Cohen's d, with thresholds of 0.5 indicating a medium effect and 0.8 indicating a large effect.

RESULTS

Baseline Characteristics

Both groups were comparable at baseline with no significant differences in demographic or clinical characteristics, including age, gender distribution, body mass index (BMI), VAS scores, WOMAC scores, ROM, and SF-36 PCS scores ($p > 0.05$).

Primary Outcomes

Pain Assessment (VAS):

Group 1 exhibited a significant reduction in VAS scores from baseline to 6 months (mean reduction: 5.8 ± 1.1), compared to Group 2 (mean reduction: 2.7 ± 0.9), with a p-value of 0.002 and a large effect size (d = 0.9).

Functional Assessment (WOMAC):

Group 1 demonstrated a greater improvement in WOMAC scores (mean improvement: 35.4 ± 6.2) compared to Group 2 (mean improvement: 20.2 ± 5.1) at 6 months, with a p-value < 0.001 and a large effect size (d = 1.2).

Secondary Outcomes

Knee Range of Motion (ROM):

Group 1 showed a significant increase in knee ROM (mean gain: 25° ± 4°) compared to Group 2 (mean gain: 12° ± 3°), with a p-value of 0.01.

Quality of Life (SF-36 PCS):

Group 1 experienced a greater improvement in SF-36 PCS scores (mean increase: 18.5 ± 3.1) compared to Group 2 (mean increase: 8.2 ± 2.4), with a p-value of 0.03.

DISCUSSIONS

The study findings indicate that the combination of IFT and US with knee exercises is more effective than TENS with exercises in reducing pain, improving function, enhancing knee ROM, and augmenting quality of life in patients with advanced knee OA over a 6-month period.

The superior outcomes observed in Group 1 (IFT + US + exercises) can be attributed to the synergistic action of interferential therapy and therapeutic ultrasound in addition to standard exercise. Interferential therapy, by delivering medium-frequency currents, penetrates deeper tissues with less discomfort than traditional TENS, resulting in effective stimulation of nerve fibers that modulate pain through both spinal segmental mechanisms and endogenous opioid release [10,11]. Additionally, interferential currents have been found to increase local blood flow, reduce edema, and facilitate muscle relaxation, all of which are essential in osteoarthritic joint rehabilitation [12].

Ultrasound therapy complements IFT by delivering mechanical vibrations that stimulate soft tissue repair and increase metabolic activity. The pulsed mode used in this study minimizes thermal effects while maximizing non-thermal benefits such as improved cell permeability and anti-inflammatory effects [13]. These mechanisms, combined with structured strengthening and ROM exercises, may enhance proprioception, muscle coordination, and joint stability, especially important in grade 3–4 OA where structural degradation is advanced.

In contrast, while TENS has been shown to be effective in pain modulation in mild-to-moderate OA, its efficacy is limited in more advanced stages. This aligns with previous research where TENS showed significant benefits in KL grade 1–2 OA, but diminished results in more severe cases [14]. The findings of this study therefore challenge the notion that all electrotherapies offer equivalent outcomes in severe OA and highlight the importance of tailored interventions based on disease severity.

The statistically significant improvement in the SF-36 physical component score in Group 1 also underscores the broader functional gains achieved with IFT and US, beyond just pain relief. Improved mobility, reduced stiffness, and greater confidence in movement may lead to higher participation in daily activities and reduced risk of falls, a known concern in elderly populations with knee OA [15].

Limitations of the study

Despite its strengths, the study has several limitations that should be considered when interpreting the results. Firstly, the sample size, although statistically powered, was relatively small, which may limit the generalizability of the findings. A larger sample would enhance the external validity of the study and potentially detect smaller effect sizes that could be of clinical significance. Secondly, the study lacked a sham control group for the electrotherapy treatments, which means that the observed outcomes may be influenced by placebo effects. A placebo-controlled design for the electrotherapy interventions could have provided more rigorous evidence regarding the true efficacy of the treatments beyond patient expectations. Thirdly, the short-term follow-up duration of six months, while practical, may not capture the long-term sustainability of the treatment effects or the progression of osteoarthritis. Longer-term studies are necessary to determine whether the improvements in pain, function, and quality of life are maintained over time. Finally, although participants were supervised during their exercise sessions, adherence to the home exercise regimen was not monitored. This lack of tracking for home-based exercise compliance could introduce variability in the results, as patient commitment outside the clinical setting may have influenced overall outcomes.

Clinical Implications

This study supports the use of interferential therapy and ultrasound in combination with structured knee exercise programs for managing severe (KL grade 3–4) knee osteoarthritis. The enhanced functional outcomes and pain relief observed in Group 1 make a compelling case for integrating these modalities into routine physiotherapy protocols, especially in resource-equipped settings.

Given the chronic and progressive nature of OA, such interventions offer a non-invasive and cost-effective means of delaying surgical interventions like total knee arthroplasty. Additionally, they may reduce reliance on pharmacological therapies, thereby mitigating risks of NSAID-associated gastrointestinal and cardiovascular side effects, which are particularly concerning in elderly populations.

CONCLUSION

In conclusion, the present randomized controlled trial demonstrates that the combination of interferential therapy and ultrasound with structured exercise therapy is significantly more effective than TENS combined with exercise in reducing pain, improving joint function, enhancing range of motion, and elevating quality of life in patients with grade 3–4 knee osteoarthritis over a 6-month period. These findings advocate for a paradigm shift in electrotherapy-based OA rehabilitation, favoring more advanced modalities like IFT and US in severe cases. Future studies with larger cohorts, sham controls, and longer follow-up durations are warranted to confirm these results and explore underlying physiological mechanisms in greater depth.

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