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Knee and Hip Kinematics during Gait following 12-week Conservative Interventions in a Case with Lower Limb Stiffness

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ABSTRACT

Aims: This case study aims to manage the post-operative complications in a patient with excessive ankle stiffness using Instrument Assisted Soft Tissue Mobilization (IASTM) and Faradic Electrical Stimulation (FES) and investigate the effects on knee and hip kinematics during gait.

Method and Materials: A 41-year-old female with post-operation complications including decreased right ankle Range of Motion (ROM) and strength underwent a 12-week of IASTM and FES. Gait analysis was performed before and after the intervention. Knee and hip angles and velocities in 3 dimensions were measured using a motion analysis system before and after the intervention.

Findings: Results showed an increased knee adduction, decreased peak knee external rotation at late swing phase, increased peak frontal plane knee velocity, frontal and transverse plane hip excursion, peaks velocities in transverse and frontal plane.

Conclusion: A 12-week IASTM and FES can improve knee and hip gait mechanics in a patient with excessive ankle stiffness.

Keywords: Biomechanics, Electrotherapy, Walking, Graston, Myofascial Release, Friction Massage

Introduction

The stiffness of the ankle plays a critical role in human movement and musculoskeletal well-being [1]. A clear understanding of ankle stiffness is essential for grasping joint mechanics, neuromuscular coordination, and the coordination of lower extremities [1]. Insufficient joint stiffness can predispose individuals to injuries, while excessive stiffness may not effectively absorb strain energy, heightening the likelihood of overuse injuries [1]. Excessive stiffness can stem from injuries, age-related alterations, or pathological conditions, resulting in compensatory movement patterns and irregularities in gait[1].

Throughout the gait cycle, the lower extremity joints work together to ensure stability, absorb shock, and generate propulsion [2]. The ankle joint undergoes dorsiflexion for shock absorption, the knee joint flexes to absorb impact, and the hip joint extends for propulsion [2]. As the cycle progresses to midstance (MS) and terminal stance, there are further joint movements where the ankle moves into plantarflexion, while the knee and hip extend to provide push-off force [2]. Subsequently, during the swing phase, distinct joint actions occur, such as dorsiflexion at the ankle and flexion at the knee to facilitate limb clearance and forward progression [2].

Disruptions in lower limb coordination can lead to altered movement patterns, resulting in a heightened risk of secondary musculoskeletal issues [3]. Restricted ankle ROM can cause compensatory changes in knee flexion and extension [4], hip movements during weight-bearing activities and necessitating greater hip flexion during the swing phase [5].

Consequently, these changes can impede the proper forward progression of the tibia over the foot during the stance phase, requiring increased hip flexion for foot clearance during the swing phase [5]. Various interventions,

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including minimal shoes[6], myofascial release [7], biofeedback [8,9], Graston [7], and FES [7], have shown promise in enhancing lower limb biomechanics. However, the specific impact of these interventions on knee and hip kinematics on the specific patient participating in the present study during gait requires further investigation. Therefore, this case study aims to evaluate the effects of a 12-week intervention involving IASTM and FES on knee and hip angles and velocity in 3 dimensions in a patient with unusually high ankle stiffness.

Method and Materials

A 41-year-old female athlete, who had been consistently exercising since the age of 10, sustained fractures of the tibia, fibula, calcaneus, and Achilles tendon rupture in her right leg at 34 years old while performing a significant jump. This resulted in infection and compartment syndrome, necessitating multiple surgeries to prevent amputation. After a challenging 3.5-year journey, the patient regained the ability to walk at the age of 37.5. During the study conducted 3.5 years post-fracture recovery, the patient, now 41 years old, had a height of 1.68 m, weighed 59 kg, had a BMI of 20.9, and leg lengths of 84.5 cm (right) and 86.5 cm (left). The participants maintained her regular workout routine, throughout the interventions. The impact of the interventions was evaluated from December 2022 to March 2023.

A 12-camera (6 Infra-red Cameras: MX T40-S, and 4 IR Cameras: Vero (v2.2); Vicon motion capture system, two Video Cameras: Bonita 720c) was used to capture the position of the reflective markers (Vicon Motion systems Ltd., Oxford, UK) during 5 gait trials at a sampling rate of 120 Hz. Fifty passive reflective markers (14 mm) were positioned on the subject according to Oxford Foot Model [10].

The interventions were assessed between December 2022 and February 2023, with a registered physiotherapist (HM) and an instructor (FKH) administering them. The program consisted of 3-session a week over a 12-week period, with interventions rotated on different days. One day FES [7] using the Beurer EM 49 Digital TENS/EMS device set at a 250 μs impulse duration and a 25 to 50 Hz frequency. On the alternate day, myofascial release [7], friction massage [7] and the Graston technic [7] (utilizing Graston Technique 5 (GT5), Graston Technique 6 (GT6), and Graston Technique 2 (CT2) tools) were applied to the calf muscles, achilles tendon, sole of the foot, and areas with adhesions. Progression was based on the participant's readiness and feedback of no pain or discomfort following the initial session, with increased time and pressure. The duration of each intervention was gradually increased by 2-3 minutes every two weeks.

The patient was instructed to walk without shoes at a comfortable pace along a 5-meter walkway until the force plates had recorded 5 clear foot strikes each.

Kinematic measurements, including angle and velocity, were obtained using fifty passive reflective markers. These markers, tracked using the Weltering marker in MSE mode, and the kinematics data were automatically processed and filtered through NEXUS software [11]. The findings were averaged over 5 trials.

Findings

The results for knee kinematics are shown in Figure 1. Results showed an increased knee adduction, decreased peak knee external rotation angle during swing phase, increased peak frontal and sagittal plane knee velocities increase in peak values.

The results for hip kinematics are shown in Figure 2. Results show increase in hip excursion in frontal and transverse plane, increased peaks in frontal and transverse plane. There was a sooner peak frontal velocity and a later transverse plane velocity in swing phase.

Discussion

This case study aimed to manage the postoperative complications in a patient with lower limb stiffness and reduced muscles strength, with kinematics approach. The study was conducted on a 41-year-old female who had recovered from right Achilles tendon rupture, tibia, fibula and calcaneus fracture Compartment syndrome and infection. The

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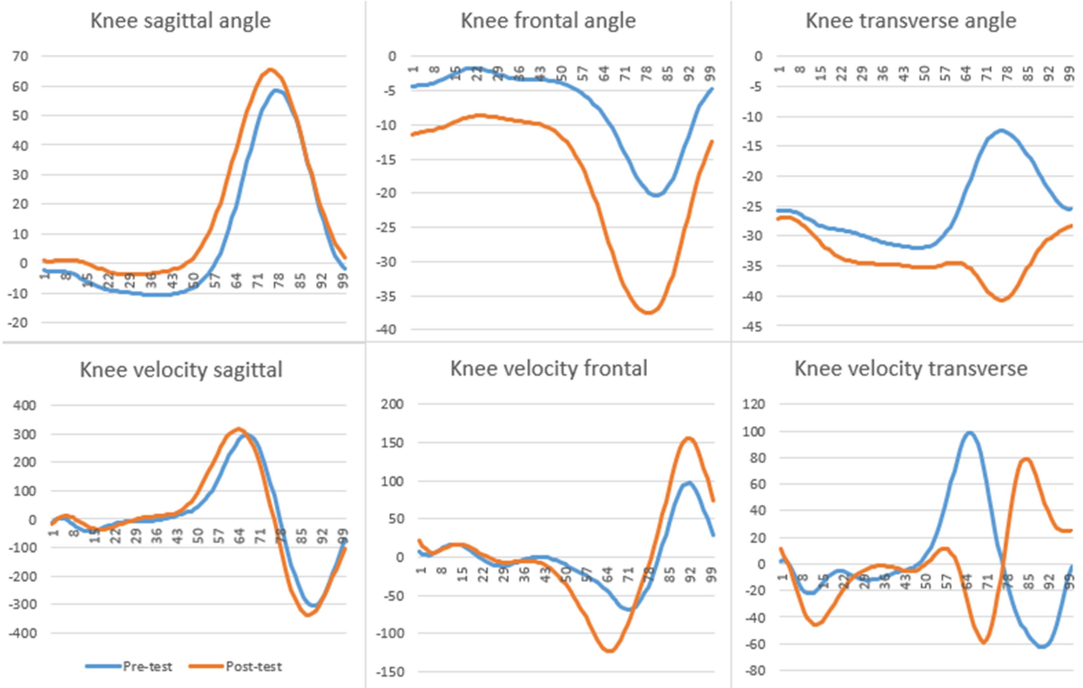

Figure 1) Knee kinematics

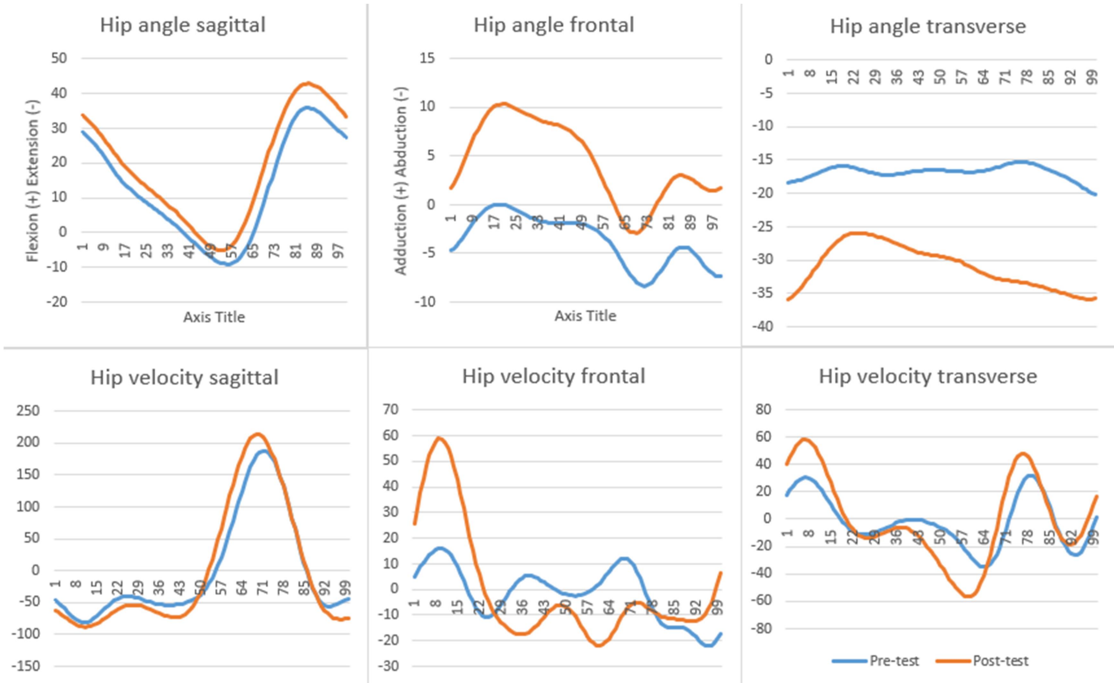

Figure 2) Hip kinematics

patients underwent a 12-week intervention program consisted of IASTM and FES on the foot, ankle and shank.

Knee motion in transverse plane shows more similar pattern to normal curve of healthy adults. The evidence suggests that both IASTM and FES can lead to improvements in knee and hip angles, and velocity during gait. This may be due to IASTM 's ability to reduce adhesions and improve tissue mobility, and FES increases muscle activation and facilitates healing which affects the knee and hip joint kinematics indirectly in the kinematic chain and leading to a more synchronised movements of lower limb joints. Combining IASTM and FES, potentially enhances the effects of each treatment method. Also, Kim et al. (2021) [12] investigated the effects of combining IASTM and ES on back pain and motor function, which showed notable improvements after the combined treatment.

Previous research shows a connection between decreased ankle dorsiflexion and knee sagittal plane motion [4] during gait and dynamic knee valgus [13]. In another study, simulated ankle plantarflexion contracture caused knee hyperextension during stance phase of gait [14]. An inadequate ROM in ankle dorsiflexion can impact knee movement, leading to decreased knee flexion during the stance phase. In severe cases of limited dorsiflexion, the knee may be pushed into hyperextension, particularly in the latter part of the stance phase. In extreme instances involving a pes equines deformity (fixed plantar flexion of the ankle), individuals may walk on the balls of their feet with toes extended, never allowing the heel to touch the ground and keeping the knee in excessive flexion throughout the stance phase. This condition is frequently seen in individuals with cerebral palsy [2]. Regarding the knee velocity, there was sooner peak knee abduction in swing phase in post-test which may be due to faster muscle activation after interventions. Hip frontal and transverse plane excursion increased in post-test, which serves more similar angles to normal values in healthy adults [15]. Hip velocity in frontal plane showed a more pronounced first peak and delayed peaks during gait cycle. Hip velocity in transverse plane showed higher peaks during the gait cycle which may indicate increased internal/external rotation ROM of hip joint.

Some limitations of this case study include the fact that it only reports on one patient, which limits the external validity of the results. It is also challenging to determine the individual contributions of IASTM and FES to the patient's improvements, as well as the impact of unilateral limb injury on the uninjured limb. It is important to assess any asymmetries between the two sides in order to fully understand the effects of the interventions.

Conclusion

In summary, this case study demonstrates the effectiveness of a 12-week program combining IASTM and FES in improving knee and hip kinematics during gait in a patient with excessive ankle stiffness. The findings indicate that this intervention could serve as an alternative or adjunct to traditional physical therapy approaches for similar complex cases. It is recommended that future research include larger sample sizes, high-quality randomized controlled trials, and assessments of interventions both individually and in combination, with follow-up evaluations.

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None declared by Authors

Authors Contribution

In this study, conceptualization by FKh, SHM, HM; Methodology by SHM, HM; Investigation by FKh, SHM, HM; Writing - original draft preparation by FKh; Writing - review and editing by FKh, SHM i, HM; Visualization by FKh; Supervision by SHM, HM; and Project administration by FKh, SHM, HM were done.

Conflicts of Interests

None declared

Ethical Permission

The experiments described in the manuscript adhered to the ethical principles of the Helsinki Declaration and were approved by the Research Ethics Committees of the Faculty of Physical Education and Sport Sciences at Tehran University (IR.UT.SPORT.REC.1401.045). The participant provided written consent.

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