Kinematic and Functional Analysis during Gait following Intraarticular Corticosteroid Injection in Patients with Acute Exacerbation of Knee Arthritis

by

Saurabhkumar Mehta

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

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ABSTRACT

Purpose
The objectives of this study include evaluation of knee joint movements following intraarticular corticosteroid injection (ICI) in patients with acute exacerbation of knee aryhjritis.. The study measured changes in spatiotemporal gait parameters, pain intensity, and functional status in the participants.
Participants
Nine adult participants with acute exacerbation of rheumatoid arthritis of the knee (aged 23 to 57) were included in the study. They all had an exacerbation of unilateral knee arthritis and attended the Rheumatology clinic at the Health Sciences Center, Winnipeg, Canada. ICI was administered to each participant in the affected knee joint.
Methods
Kinematic data for the affected knee and spine was obtained by Vicon Motion Analysis System (Oxford, UK) during gait. Spatiotemporal gait parameters were obtained using the GAITRite® system (CIR Systems Inc. Clifton, NJ 07012). Participants performed five trials each for gait and stair climbing. Pain intensity was measured by a 10 cm vertical VAS. The Knee injury and Osteoarthritis Outcome Score (KOOS) was used to obtain functional outcome information. Data was collected before the ICI and after 7-10 days following ICI.
Analysis
Movement excursion for the affected knee joint flex/ext, hip abd/add, ankle DF/PF, spine side flexion, and spine forward flex/ext angle on the affected side were the outcome variables extracted from the kinematic data. Kinematic data was exported, conditioned, and processed using custom MatLab 7 software for analysis. The gait cycle was separated into swing and stance phases. Average curves for each outcome variable were analyzed pre and post-injection with a point to point paired t-test in all the participants. Cadence, velocity, bilateral stride length, bilateral step length, step width, bilateral step time, double support percentage, and ipsilateral single support percentage were the spatiotemporal parameters that were compared before and after ICI. Pain intensity and KOOS score were also compared using paired t-tests were computed for testing these variables. Differences for $p<0.05$ were considered significant.
Results
Significant improvement in the flex/ext excursion of the affected knee joint was observed following ICI. Movement excursion for ankle DF angle also improved following ICI. Participants also showed significant improvement in cadence, velocity, bilateral stride length, bilateral step length, step width, double support percentage, and ipsilateral step time. Pain level reflected by VAS and functional status as described by different subscales of KOOS showed significant improvement as well following ICI.
Conclusions
The study demonstrated a short-term effect of ICI-induced pain relief on knee joint functions in patients with acute exacerbation of rheumatoid arthritis of the knee patients. The study concluded that knee joint movements, gait pattern, and overall quality of life improve markedly following ICI. Future research should determine the long-term effects of ICI in acute exacerbation of rheumatoid arthritis of the knee on knee movement, pain and function.

ACKNOWLEDGEMENTS

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I also want to acknowledge Jung Mok Han, a graduate engineering student, for designing custom-made script for analyzing gait data. The precise data analysis performed for the study was only possible with his MatLab expertise.

Special thanks is reserved for my colleagues and students in the Pain Research Laboratory. Many thanks for being my guinea pigs and allowing me to practice and figure out Vicon system, which could be puzzling at times. Also, to the office staff at the School of Medical Rehabilitation for assisting with necessary paper work and made sure that I never missed any deadline.

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Dedication of this thesis is to the almighty god, whose blessings are always with us, we just need to be more appreciative of his ways of helping us.

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INTRODUCTION

Joint arthritis is one of the most prevalent conditions affecting the elderly population. According to a recent report by Health Canada, approximately 1 in 6 Canadians aged 15 years and over reported having arthritis as a long-term health condition. Two-thirds of those with arthritis were women and nearly 3 of every 5 people with arthritis were younger than 65 years of age. The report also estimated that by the year 2026, six million Canadians older than 15 years of age will have arthritis (Health Canada, *Arthritis in Canada. An ongoing challenge.* Ottawa: Health Canada 2003). The economic burden of arthritis disorders on the Canadian economy has been found to be very significant. In a recent study, it was shown that the costs related to osteoarthritis in Canada are substantial and are often underestimated (Gupta, Hawker, Laporte, Croxford, & Coyte, 2005)

Knee joint arthritis is a common form of arthritis observed in older adults. Pain, stiffness, joint effusion, and difficulty in various activities of daily living (ADL) are common symptoms with knee arthritis. It has been shown that individuals with knee osteoarthritis (OA) utilize different movement and muscle activation patterns compared to those without OA while walking and descending a step. These alterations may interfere with the ability to dissipate loads possibly leading to disease progression at the knee joint (Childs, Sparto, Fitzgerald, Bizzini, & Irrgang, 2004). Significantly reduced walking speed, shorter stride length and prolonged stance phase of the gait cycle have also been reported in subjects with knee arthritis during gait (Al Zahrani & Bakheit, 2002). Apart from walking, individuals with knee arthritis also experience difficulties with some other activities of daily living. In a recent study, it was observed that the participants with knee

osteoarthritis demonstrated reduction in knee flexion and delayed onset of vastus lateralis activity during the stance phase of stair descent compared to control subjects without knee arthritis (Hinman, Bennell, Metcalf, & Crossley, 2002).

The symptoms of pain, synovitis, and difficulties with ADL are more pronounced during the active inflammatory stage of knee joint arthritis. The alterations in knee joint kinematics during ambulatory activities are complex and severe during this phase. Gait patterns of patients with active knee joint inflammation secondary to rheumatoid arthritis to that of patients with knee joint rheumatoid arthritis with low disease activity were compared during level walking. Significant gait differences were observed between rheumatoid arthritis patients with active inflammation in the knee joint without progressive destruction and those with joint destruction and minimal inflammation (Sakauchi et al., 2001) .

Intraarticular steroid injections have been used successfully in the treatment of knee arthritis. In a randomized, double-blind trial, patients with OA of the knee received intraarticular steroid injections (34 patients) or saline (34 patients) into the affected knee every 3 months for up to 2 years. The progression of joint space narrowing, WOMAC, knee joint ROM, and pain intensity were measured to assess long-term efficacy and safety of ICI. Results indicated that long-term use of intraarticular steroid injections was safe and clinically effective for patients with symptomatic knee osteoarthritis (Raynauld et al., 2003). Additionally, in patients with knee rheumatoid arthritis, intraarticular steroid treatment has been found to be an effective symptomatic and cartilage protective treatment (Weitoft, Larsson, Saxne, & Ronnblom, 2005).

Researchers have measured kinematic changes during gait and stair climbing following intraarticular knee joint injection in adults (Shrader, Draganich, Pottenger, & Piotrowski, 2004) as well as children (Brostrom, Hagelberg, & Haglund-Akerlind, 2004). Shrader et al (2004) measured kinematic gait parameters before and fifteen minutes post-injection. The study did not provide a clear explanation of pain and functional status before and after the treatment. Others suggest 24 hour post-injection rest to maximize a prolonged duration of clinical response following intraarticular steroid therapy for knee synovitis (Brostrom et al., 2004; Chakravarty, Pharoah, & Scott, 1994). Brostrom et al (2004) have clearly addressed this principle suggesting the participants not walk for at least 24 hours and avoid physical exercise following intraarticular corticosteroid injections. They used a 3-dimensional (3D) gait analysis system for measuring lower limb kinematics in these patients. The study focused only on children with juvenile idiopathic arthritis and the injections were given in more than one joint. The function of stair climbing was not assessed in these children. As a result, it is not possible to extrapolate these findings in older adults receiving intraarticular corticosteroid injections (ICI) for the unilateral exacerbation of knee arthritis. However, the study does demonstrate the comprehensive use of 3D gait analysis system following ICI therapy. It also signifies the importance of comparing the knee kinematics of gait before and at least 24 hours post-injection to facilitate better understanding of these alterations.

Other studies have reported improvement in gait patterns and ground reaction forces (Tang et al., 2004), increase in knee muscle strength (Tang et al., 2005), and improvement in maximum voluntary contraction (MVC) in quadriceps (Hassan, Doherty,

Mockett, & Doherty, 2002) following intraarticular injection in patients with knee arthritis.

Detailed kinematic analysis of the knee joints bilaterally in older adults following such intervention has not been investigated comprehensively. The proposed study presents a detailed kinematic analysis of the knee joints bilaterally following ICI therapy in patients with a unilateral exacerbation of knee arthritis. Knee joint kinematics and spatial-temporal parameters during gait and stair climbing; which are two of the most important daily functions were investigated. The study would help physiotherapists to understand the knee joint kinematics following ICI therapy for knee joint arthritis and would facilitate development of more suitable exercise program for patients with knee arthritis.

REVIEW OF LITERATURE

With the aging population, there is a dramatic increase in the prevalence of arthritis. In Canada, knee joint arthritis is the most common form of joint disease affecting the middle-aged and elderly population. Deaths due to arthritis and related conditions were reported to be higher than asthma or HIV/AIDS, especially among women. In a publicly-funded health care system this is significant; the economic burden to Canadian society because of arthritis was estimated at $ 4.4 billion in 1998 (Health Canada, 2003). The mammoth economic burden of arthritis has also been reported in other developed countries such as Australia, Germany, and France (Hulsemann et al., 2005; Rat & Boissier, 2004; Lapsley, March, Tribe, Cross, & Brooks, 2001)

Symptoms of Knee Arthritis

Patients with knee arthritis suffer from joint pain, fatigue, impaired mobility, and difficulties with several ADL. Chronic pain secondary to rheumatoid arthritis has been found to cause joint contractures, muscle atrophy, deformities, valgus instabilities, and inability to walk (Grassi, De Angelis, Lamanna, & Cervini, 1998). Patients with knee rheumatoid arthritis also exhibit impaired muscle strength in the quadriceps muscle, affecting their ambulatory activities and physical functions (Hakkinen et al., 2006). In addition to physical symptoms such as knee pain, morning stiffness, crepitus, bony tenderness or enlargement associated with knee osteoarthritis (Handy, 1996), significant mental distress (Dickens, Jackson, Tomenson, Hay, & Creed, 2003) and anxiety (VanDyke et al., 2004) are also reported to be associated with arthritis.

Knee Arthritis and Gait

Walking is an important function of daily living. Difficulty with walking can affect quality of life. The kinematics of the lower extremity can be altered in the presence of pain and muscle weakness in patients with knee arthritis. There is evidence to suggest alterations in knee kinematics during walking in this population. Shorter stride length, reduced walking velocity, and longer stance phase have also been reported (Al Zahrani et al., 2002). Significant alterations in knee kinematics and muscle co-activation have been found in the patients with knee arthritis and are considered to be a strategy to avoid pain while walking (Childs et al., 2004; Hinman et al., 2002).

Intraarticular corticosteroid injections in Knee Arthritis

Pain relief and improvement of ambulatory functions are the most important effects following ICI in the arthritic knee joint. Intraarticular steroid injections have been described as safe for long-term use in patients with symptomatic knee arthritis (Raynauld et al., 2003). They are considered the primary treatment in patients with knee rheumatoid arthritis (Lundberg, Grundtman, Larsson, & Klareskog, 2004) and are also believed to reduce synovitis and protect cartilage (Weitoft et al., 2005). The actual impact of intraarticular knee injections and resultant pain reduction on various kinematic and kinetic parameters of the treated and untreated knee joints during various functional activities has also been measured (Shrader et al., 2004; Brostrom et al., 2004; Tang et al., 2004)

Lower Limb Joint Kinematics, kinetics, and muscle strength following Intraarticular corticosteroid and hyaluronate injections

3D Motion Analysis System is frequently used for measuring lower limb joint movements during gait. Kinematics of lower limb joints have been measured in patients with knee arthritis in past (Nadeau, McFadyen, & Malouin, 2003; Webster, Wittwer, & Feller, 2003).

Shrader et al (2004) investigated the kinematics and kinetics of the arthritic knee joint before and after ICI. They hypothesized that a pain-relieving intraarticular injection of the painful osteoarthritic knee would result in increased loading of the medial compartment of the affected knee during gait and stair stepping. Twenty one participants with knee osteoarthritis and the same number of controls were recruited for the study.

Gait and stair-stepping kinematics were measured in the participants. All the participants with knee arthritis received corticosteroid injections in their affected knee joints. Four of the patients with bilateral knee arthritis received injections in both knees. A multicomponent force platform was used to analyze ground reaction forces. Joint kinematics were measured using 3D digitizing and motion analysis system. Three trials of both gait and stair-stepping were recorded for each participant. The arthritic group was then injected with corticosteroid in their knee joints. After a fifteen minute rest period, the gait and stair trials were performed again.

Gait velocity and cadence increased significantly ($p<0.05$) following the injection. However, no significant changes were observed in any of the 3D angles, flexion-extension, abduction-adduction, or internal-external rotation at the knee or ankle after the injection during walking. The hip flexion-extension angles were the only kinematic parameters that showed significant change ($p=0.03$ for extension and $p=0.02$ for flexion). During stair stepping, time on the step decreased post-injection, but was not statistically significant. Lower limb joint kinetics showed significant improvement post-injection during walking, whereas they were unchanged during stair climbing (Shrader et al., 2004). It is possible that the kinematics of lower limb joints that were found to be unchanged immediately following ICI in the arthritic knee joint might be different, if measured one week later. Some literature recommends avoiding weight bearing in the knee arthritis patients for at least twenty four hours post-injection (Brostrom et al., 2004; Chakravarty et al., 1994).

Brostrom et al (2004) measured the impact of pain relief and reduction in acute inflammation on lower extremity kinematics and kinetics in patients with juvenile

idiopathic arthritis. Eighteen children between the ages of five to sixteen years were recruited in the study. Up to ten lower extremity joints were injected with ICI unilaterally or bilaterally in these patients. Pain measurements were recorded using 0-100 mm Visual Analogue Scale (VAS) specially devised for children. Three-dimensional joint kinematics were recorded for gait and stair climbing using a 6-camera Vicon Motion Analysis System (Oxford, UK). Two force-plates were used for measuring ground reaction forces to produce joint kinetic information. The children were instructed to refrain from weight-bearing for 24 hours and also to avoid physical exercise post-injection. The second session was performed 8-17 days post-injection.

Kinetic parameters were normalized to body weight and stride parameters were normalized to height. Gait patterns of the hip, knee, and ankle joint angles and joint moments pre- and post-injection were derived from an average gait cycle. The peak values for lower limb joint moments and kinematics were analyzed. Two-way analysis of variance revealed a significant increase ($p = 0.03$) in peak knee and ankle joint angles during level walking after ICI to the lower extremity. Knee, hip, and ankle joint moments all increased significantly ($p<.05$) following ICI. Hip kinematics were found to be unchanged following the treatment. Pain measurements (0-100 cm VAS) showed significant reduction in pain ($p=0.001$). Overall, the study provides satisfactory analyses of measuring the impact of pain relief and reduced inflammation on gait kinematics. However, there are certain limitations of this study. Many of the participants were suffering from arthritis in multiple joints. The ICI injections were given to more than one joint in these cases. The age group involved in the study consists of children between the ages of 5 to 16 years. Since older adults with arthritis may not be as active compared to

young children, the kinematic comparisons may not be replicated in older adults with acute knee arthritis. Finally, level walking is the only function of daily living that was assessed in this study and effects of ICI on stair climbing remains unexplored (Brostrom et al., 2004).

The effect of intraarticular hyaluronate injection to the knee joint on gait patterns and ground reaction forces (GRFs) in patients with knee osteoarthritis was assessed by Tang et al (2004). Fifteen patients with knee osteoarthritis and the same number of controls were recruited for the study. A Vicon Motion Analysis System with AMTI force plates was used to obtain kinematic and kinetic data during gait. The major outcome variables were saggital GRFs and the gait parameters of velocity, cadence, step length, and stride time. These parameters were analyzed before and 1 week, 3 months, and 6 months after intraarticular hyaluronate injection.

The study confirmed that all the gait parameters and saggital GRFs improved after the intraarticular hyaluronate injections in arthritic knee joints. The effect was of long duration and these changes remained significant even six months after the injection. The study demonstrates long-term effects of pain relief in patients with knee arthritis on gait parameters (Tang et al., 2004).

Knee Muscle strength following intraarticular pain relieving injections

Apart from joint kinematics and kinetics, muscle strength has also been assessed in patients with knee arthritis following intraarticular injections. The impact of intraarticular hyaluronan injections was assessed on concentric and eccentric muscle strength of knee flexors and extensors in patients with bilateral knee osteoarthritis. A total

of 25 patients with bilateral knee osteoarthritis were recruited for the study. The KIN-COM isokinetic dynamometer was used to test the concentric and eccentric muscle strength of the knee flexor and extensor muscles through 10-90 degrees of knee range of motion. Intraarticular injections of 1% hyaluronan were injected in both the knee joints once a week for five consecutive weeks. The same protocol for assessing knee muscle strength was employed one week after the last injection. Patients abstained from knee muscle strengthening exercises during the total period of six weeks. Paired t-tests were computed for each patient to compare concentric and eccentric muscle strength. Results from the study indicated that intraarticular injection of hyaluronan is effective in increasing knee muscle strength in knee osteoarthritis patients (Tang et al., 2005).

Hassan et al (2002) investigated the effects of knee pain relief on quadriceps function, proprioceptive acuity, and postural stability in patients with knee osteoarthritis. A cross-over, within-subject, double blind design was employed. Sixty eight patients with unilateral or bilateral OA knee were recruited for the study. Intraarticular injections of either bupivacaine (local anesthetic) or saline were given to each patient. The alternative agent was injected two weeks later. Assessor and patient were both blind to the order of injection. The measurements for postural sway were taken using the Balance Performance Monitor (SMS Sanders Healthcare, Harlow, Essex CM19 5TL, UK). Proprioception acuity was evaluated by the ability to reproduce passive positioning of the affected knee joint with the eyes closed. A modified Tornwall chair was used to measure maximum voluntary contraction for quadriceps. Pain measurements were obtained using 0-100 mm VAS. Data was collected from two sessions during each intervention; prior to knee joint injection and one hour after the injection. The same procedures were repeated

during the crossover intervention two weeks later. The pain relief resulted in improved maximum voluntary quadriceps contraction in the participants after both the interventions, including saline injection. No improvements were noted in proprioception or static postural stability in these patients with either the bupivacaine or saline (Hassan et al., 2002).

Overall, previous studies have demonstrated positive effects of intraarticular pain relieving injections on knee joint kinematics and muscle strength in knee arthritis patients.

Vicon Motion Analysis System

Vicon Motion Analysis system (Oxford, UK) has been used extensively in the past for 3D motion capture during gait in knee pathologies (von Porat, Henriksson, Holmstrom, & Roos, 2007; Segal et al., 2006; Burks & Keegan, 2006; Segal et al., 2006). The system uses high resolution video cameras to capture 3D motion and it is reproduced in digital environment. Movement is recorded by an array of video cameras and reproduced in a digital environment.

GAITRite®

The GAITRite® (CIR Systems Inc. Clifton, NJ 07012) system consists of an electronic walkway with sensors arranged in a gridlike pattern to identify footfall contacts closing under the pressure of foot when a participant walks over the walkway. During gait, the system captures the geometry and the relative arrangement of each foot contact as a function of time. The application software processes raw data into footfall patterns and computes the spatiotemporal gait parameters. The literature supports reliability and

validity of the GAITRite® carpet for extracting spatial and temporal parameters for gait (Parmar, Shyam Kumar, & Harper, 2006; Webster, Wittwer, & Feller, 2005; Menz, Latt, Tiedemann, Mun, & Lord, 2004; Bilney, Morris, & Webster, 2003).

Visual Analogue Scale (VAS)

The Visual Analogue Scale (VAS) has been widely used to measure pain intensity in patients with knee arthritis (Burch, Tarro, Greenberg, & Carroll, 2008; Itoh, Hirota, Katsumi, Ochi, & Kitakoji, 2008; Sun et al., 2006; de Miguel, Cobo, Uson, Bonilla, & Martin, 2006). The scale is a 100 mm line and its anchors are 'no pain' and 'pain as bad as it can be'. Patients are advised to put a mark on the line that best describes their pain intensity over the past 24 hours. The distance from the "no pain" anchor is measured in order to quantify the pain intensity on a continuous scale. The VAS is a valid and reliable tool for measuring pain intensity in young and older adults (Summers, 2001; Tiplady, Jackson, Maskrey, & Swift, 1998; Dixon & Bird, 1981; Scott & Huskisson, 1979).

Knee injury and Osteoarthritis Outcome Score (KOOS)

The Knee injury and Osteoarthritis Outcome Score (KOOS) is an extension of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and one of the commonly used patient-relevant outcome measures. The KOOS is a patient-relevant 42 self-explanatory and self-administered questionnaire with five subscales including pain, other symptoms, functions in daily living, sport and recreation function, and knee related Quality of Life. The KOOS has been validated for use in patients with OA of the knee (Xie et al., 2006; Roos & Toksvig-Larsen, 2003).

Pain and inflammation associated with knee arthritis lead to impairment of movement and difficulties at various daily activities. The negative impact of arthritic pain on gait and other daily functions has been confirmed in the literature. The effect of pain relief following some intervention to arthritic knee joints on daily functions is beginning to be understood. Gait kinematics and kinetics have been investigated in the past following ICI therapy using force plates and motion analysis. However, the short-term effect of ICI on knee joint kinematics during walking in patients with arthritis of the knee still remains unclear. The present study measured bilateral knee joint kinematics and spatiotemporal gait parameters during walking and compared them 7-10 days following ICI in patients with knee arthritis. The study also measured participants' ability to use stairs following ICI.

OBJECTIVES AND HYPOTHESES

Objectives

The overall general objective of this study was to measure lower limb movements during gait, spatiotemporal gait parameters, and functions in patients with knee arthritis pre- and post-ICI. The specific objectives included

1. Comparison of hip abduction/adduction (abd/add), ankle dorsi/plantar flexion (DF/PF), knee flexion/extension (flex/ext) movements in participants during gait and stair climbing following ICI in arthritic knee joint.
2. Comparison of spatiotemporal gait parameters following ICI
3. Comparison of pain and functions in participants following ICI.

Hypotheses

It was hypothesized that there would be significant increase in the movement excursions of affected knee joint during the stance phase of gait and step/stair climbing following ICI in the arthritic knee. The spatiotemporal parameters were also expected to improve following ICI. It was also hypothesized that knee pain and functions would significantly improve following ICI.

RESEARCH METHODS

The following paragraphs provide a detailed description of the participants, study design, and instruments that were used in the study.

Participants

Nine participants (all females) suffering from exacerbation of rheumatoid arthritis of the knee joint were recruited for the study. The major inclusion criterion was the evidence of acute exacerbation of knee arthritis in one of the knee joints. Other inclusion criteria included the participant's ability to ambulate without any mobility aid. Participants were also expected to be cognitively intact and be able to follow the instructions during the study.

Participants with an exacerbation of arthritis in both the knee joints, acute joint pains in any other lower extremity weight-bearing joints, or receiving simultaneous treatment for knee arthritis in any form were excluded from this study. Other important exclusion criteria were participants with neurological disease, recent injury, and

deformities or contractures in spine and lower limbs. Table 1 illustrates the characteristics of the study population.

Recruitment

Eligible participants attending the Health Science Centre Rheumatology Clinic, Winnipeg, Manitoba, who were about to undergo intraarticular corticosteroid injection for an inflamed knee joint were approached by their rheumatologist regarding the opportunity to participate in the study. General study details were discussed with them by a research nurse. Participants were referred to the Pain Research Laboratory for a more detailed explanation of the study. A consent form was developed which specifically explained the study details in lay terminology (See Appendix A). It allowed participants to ask questions, and enabled them to make an informed decision regarding involvement in the study. The participants signed the consent form after reading it. The consent form, study protocol, participant information form, and pain and functional measurement tools were approved by the University of Manitoba Health Research Ethics Board (H2005: 137). Participants were advised that they were free to withdraw from the study at any time.

Study Design

The study was a comparative cross-sectional study. Comparisons for lower limb joint kinematics and spatiotemporal gait parameters were made before and 7-10 days after the ICI treatment for each participant. Pain intensity and functional status were

averaged for all participants and compared pre- and post-ICI treatment. Each participant served as her own control.

Instrumentation

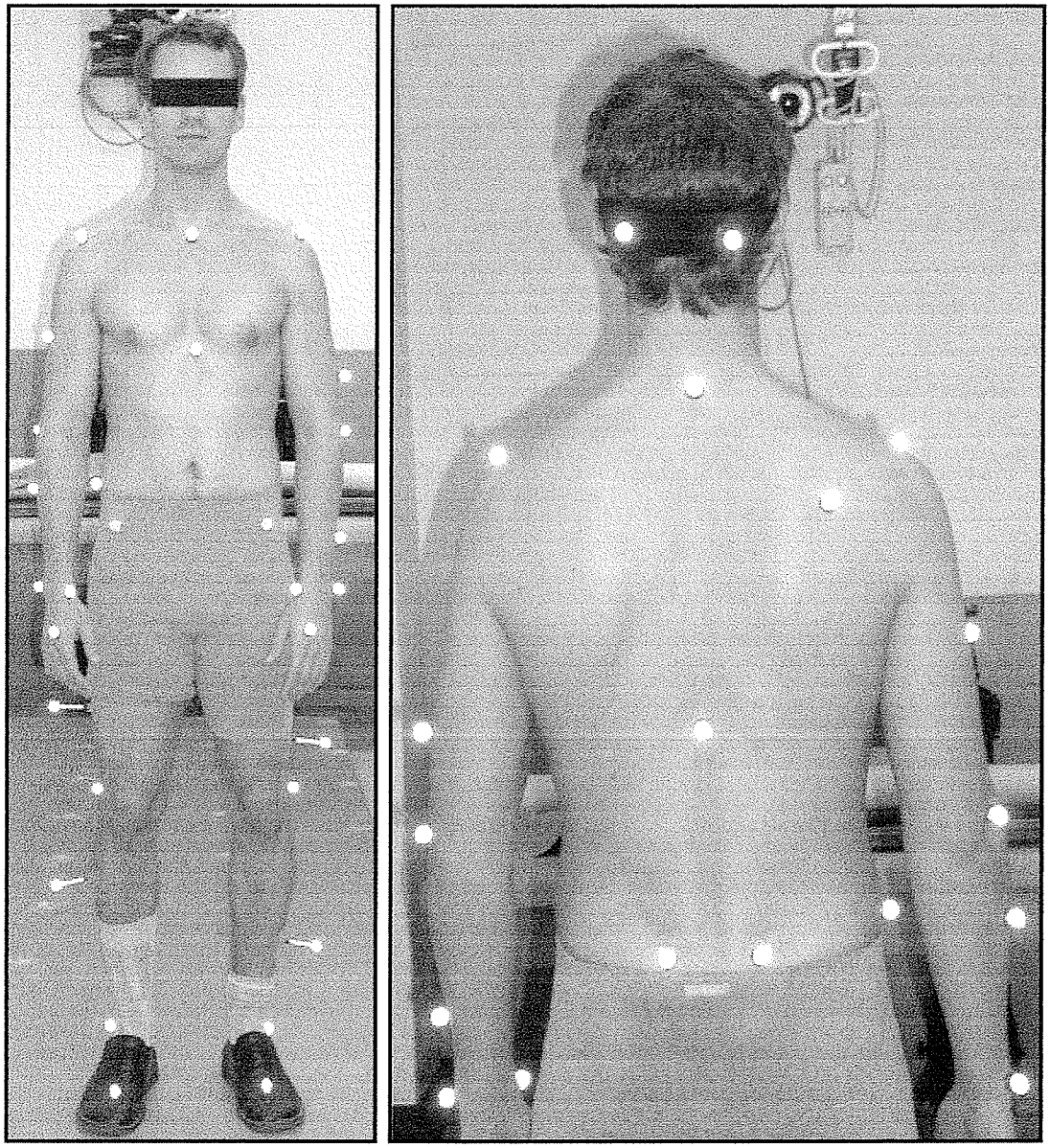
Motion Analysis System

The Pain Research Laboratory at the School of Medical Rehabilitation is equipped with a 6-camera Vicon 460 V- Motion Analysis System (Oxford, UK). Kinematic data for lower limb joints were obtained with this Motion Analysis System.

Movement is recorded by an array of video cameras and reproduced in a digital environment. The motion capture space (capture volume) is surrounded by six high-resolution cameras. Each camera has a ring of LED strobe lights fixed around the lens. Reflective markers are attached to the participant at pre-defined positions. The anatomic locations are demonstrated in Figure 1. As the participant moves through the capture volume, light from the strobe is reflected back into the camera lens and strikes a light sensitive plate creating a video signal. The Vicon data station controls the cameras and strobes and collects these signals at a frequency of 120 Hz, along with any other recorded data (analogue signals from force plates or EMG).

The Vicon software takes the two-dimensional data from each camera, combining it with calibration data to reconstruct the equivalent digital motion in three dimensions.

Figure 1. Marker Attachment for Plug-in Gait Model



GAITRite®

Spatiotemporal gait parameters were obtained by the GAITRite® system (CIR Systems Inc. Clifton, NJ 07012). The GAITRite® carpet was kept over the capture volume of Vicon system. The GAITRite® was triggered simultaneously with Vicon for data collection during each trial.

Pain and Functional Measurements

Pain intensity was measured by a 100 mm vertical VAS. The participants were asked about their average pain intensity over the past 24 hours. The anchors of the VAS were 'no pain' and 'pain as bad as it can be'. Functional status was obtained by the Knee injury and Osteoarthritis Outcome Score (KOOS). Both the VAS and KOOS were administered on both occasions that is pre- and post-ICI.

Data Collection Procedure

Participants attended the Pain Research Laboratory for kinematic assessment before the corticosteroid injection was given into the affected knee joint. After this session, they went back to the Rheumatology Clinic for the ICI to the knee joint. Participants returned to the Pain Research Laboratory after 7-10 days for the second kinematic data collection.

Anthropometric data was collected and maintained for each participant. Physical assessment was performed for each participant before the data collection. A joint caliper was used for measuring the participant's girth at the knee and ankle joints bilaterally. The medial and lateral knee joint line and bimalleolar area were used as reference points for

girth measurement at the knee and ankle joints respectively. Other anthropomorphic characteristics that were collected included body weight, height, and leg length. VAS and KOOS score were obtained before the data collection procedure. The same investigator performed all of the measurements on both occasions.

There were several steps in the data collection procedures. They can be conveniently divided into three categories: equipment preparation, participant preparation, and actual data collection during motion capture with the Vicon and walking using the GAITRite® system.

Equipment Preparation – Calibration of the Vicon Motion Analysis System was performed in static and dynamic modes using reflective marker strobes for each of the modes. The GAITRite® carpet was attached to a second computer for collection of spatial and temporal parameters and variability between each step during level walking. Required anthropometric characteristics related to the participant were entered in preparation for data collection.

Participant Preparation – All the participants were asked to wear shorts in order to attach markers to the pre-defined anatomical locations using the plug-in gait model provided by the Vicon Motion Analysis system. They were advised to wear comfortable walking/running shoes for the session. At this stage they were given one practice walking trial to familiarize themselves with the camera capture area and study protocol. The participants were instructed to walk at a self-selected and comfortable pace.

Data Collection – Each participant was identified with a code to maintain confidentiality. The accessibility of these codes and the database was password protected and Personal Health Information Act (PHIA) compliant.

Level Walking – The GAITRite® carpet was positioned in the centre of the Vicon Motion Analysis capture volume. The capture volume was approximately 3 meters long and 2 meters wide, which was large enough to accommodate two full gait cycles for each participant. Participants were asked to start walking approximately 1 meter away from the ends of the GAITRite® carpet in order to develop their natural stride before entering the capture area. Vicon and GAITRite® data was collected simultaneously. After each trial, primary data conditioning was done to ensure that the trial was satisfactory. Each trial was carefully re-played to ensure that there were no major gaps in data capture and the data was continuous. Five walking trials at a self-selected pace were collected per session. A short break between walking trials was allowed if required.

Step/Stair climbing – If able, participants were also asked to ascend and descend stairs. The height was 18 cm for both step and stairs. The stairs were positioned in the middle of the capture volume of Vicon system and had two steps. Participants climbed up on the stairs, turned around, and descended at their self-selected pace. They were requested not to hold the banister unless they had any balance disturbance. If participants were unable to use the stairs due to pain, they had an option of using a step. The step was positioned in the capture volume as well and participants went up and down the step at their self-selected pace for five trials. Participants who could perform both, the stairs and the step, were asked to complete five trials each. They were allowed to stop if at any time they experienced severe pain and were unable to continue.

After the data was collected, participants returned to the Rheumatology Clinic to receive ICI in the painful knee joint. They returned for the post-injection data collection 7-10 days following the initial assessment and ICI.

DATA ANALYSIS

Data conditioning for the kinematic data was initially performed in the Vicon software. Each trial was manually checked in order to ensure the continuity of data. Vicon software has a function that allows filling any gaps in data points if the data is not continuous. Missing data points are created by considering the relative position of marker trajectories during the discontinuous part of data. In this study, the trial was considered for analysis only if there were six or less missing data points. Bilateral hip, knee, ankle, and spine angles for x, y, and z axes were exported in an ASCII format. The X, Y, and Z coordinates the ankle and toes markers bilaterally were also exported.

Custom scripts were developed in MatLab v 7.1 (The MathWorks Inc., Natick, MA, USA). The Z coordinates of the ankles and toes bilaterally were used to separate gait cycles into swing and stance phases. The number of stance phases available varied between pre- and post-ICI sessions in each participant. Based on the number of stance phases available for comparison in post-ICI session, the same number of stance phases were selected for comparison from pre-ICI session. Five to eight stance phases were obtained in total for each participant from each data session. Ipsilateral (the injected side) hip abd/add, ankle DF/PF, and knee flex/ext angles were extracted for further analysis.

Angles for each of these movements during the stance phase were transferred to an Excel (Microsoft, WA, USA) spreadsheet for analysis. Each stance phase was offset to start at zero by taking an average of the first five data points and subtracting the whole column from that average value. Five to eight stance phases were analyzed for each kinematic variable for pre and post-injection data in each participant and also for the

group. The first sixty data points for each movement were selected for comparison within each participant, which represented approximately 85% of stance phases.

Two gait cycles were obtained from each of the five trials per session for each participant on the GAITRite® carpet. Mean values for cadence, velocity, bilateral stride length, bilateral step length, step width, bilateral step time, double support percentage and ipsilateral single support percentage (percentage of time spent exclusively on ipsilateral side during stance) during a gait cycle were compared before and after the injection between the participants.

The VAS score was calculated by measuring the distance (mm) from zero to the mark the participant made indicating pain intensity. An average score for the participants was obtained for pre- and post-ICI sessions. Similarly, knee girth was obtained (cm) for the affected knee joint and average scores were calculated for the participants pre- and post-ICI. Percentage change in VAS was calculated to look at the relationship between pain and peak knee flexion angles.

KOOS scores were normalized and calculated separately for each subscale in a participant. The normalized scores were compared between the participants for each subscale before and after the ICI. Percentage change for VAS scores was obtained to examine the relationship of pain with QOL and ADL subscales.

Participants were scored on the ability to perform steps and stairs. Individual scores were normalized to the maximum obtainable score (see table 3). For example, a participant who was able to perform two trials of the single step and no stairs prior to the ICI would be assigned a score of 8. Post-ICI, if the participant was able to perform all five single steps and all five trials of the stairs, she would be assigned a score of 0. The

raw scores are normalized to the maximum possible score. A normalized score of 100 indicates no difficulty and 0 indicates extreme difficulty. The formula is as follows.

$$\text{Normalizes percentage} = \text{Maximum percent possible} - \frac{\text{raw score (100\%)}}{\text{Maximum possible raw score}}$$

Calculation Example – raw score pre is 8 and raw score post is 0.

Pre $100-\frac{8(100)}{10} = 20$

Post $100-\frac{0(100)}{10} = 100$

STATISTICAL ANALYSIS

Paired t-tests were performed for each data point on the stance phase for a variable. The point-to-point t-test shows differences at different stages of stance phase and identifies change in pattern of movement. Sixty paired t-tests were performed to identify regions of difference over the entire stance phase. Since there are 60 inferential tests (a paired t-test at each joint angle over sixty data points), the chances of Type I error are greater. In order to effectively counter a Type I error two strategies were implemented. First, the level of significance was accepted at $p<0.01$ while comparing lower limb joint angles during stance phase. Also, a technique was adopted to only accept trends in data that occurred over three consecutive points as compared to accepting any single comparison showing a significant result at an individual joint angle. This method of analysis is based on a mathematical probability model where the likelihood of having three consecutive random type 1 errors is less than 0.01. The technique not only counters

against Type I errors, but it also guards against Type II errors and it has been employed in past for similar comparisons (Hodges, 2006; Hiemstra, Webber, MacDonald, & Kriellaars, 2000). One of the other common methods for comparing joint angles include comparing the mean peak values for the joint angles (Maly, Costigan, & Olney, 2006; Brostrom et al., 2004). Peak joint angles during stance phase were also compared for each movement between participants pre- and post-ICI.

P values were plotted to ascertain where in the stance phase the differences were significant for a particular joint angle. Peak joint angles for each variable were also compared as a group for all the participants using paired t-tests. Mean values for cadence, velocity, bilateral stride length, bilateral step length, step width, bilateral step time, double support percentage, and ipsilateral single support percentage pre- and post-ICI were also compared between the participants using paired t-tests. Average values for all participants for KOOS and VAS pain scores pre- and post-ICI were compared using paired t-tests. Wilcoxon Signed Rank Test was used if the normality test failed. Pearson correlation test was used for examining the relationship between change in VAS with peak knee flexion angle and change in VAS with QOL and ADL subscales. Sigma Stat V.3.1 software (SPSS, Chicago, IL) was used for statistical analyses. As mentioned earlier, point-to-point comparisons of joint angle were considered significant at $p<0.01$, whereas other results were considered significant at $p<0.05$.

CLINICAL RELEVANCE

The study provided detailed analyses of kinematic changes following ICI in arthritic knee joints. The change in pain level and functions were also found to be

improved following ICI. These findings help to explain improvements in knee functions following pain relief secondary to ICI. The study will help to understand a short-term effect of ICI in patients with acute exacerbation of rheumatoid arthritis of the knee and will help physiotherapists to design a proper exercised routine for these patients.

LIMITATIONS

Nine participants were included in the study and eight participants were tested pre- and post-ICI in knee joint. One participant did not return for post-injection session. Power of the study was not calculated, as this was a pilot study. Based on the variability of these individuals and the magnitude of change, future studies should calculate the power of the study and determine number of participants before the data capture.

There were no gender preferences in selection criteria; however, all the participants recruited were female. Hence, the data does not represent the kinematic alterations following ICI in male participants.

The study measured short-term effects of ICI on gait kinematics following ICI. Future studies could measure long-term effects of ICI on gait kinematics. In addition, measurement of muscle activation patterns for lower limb and trunk muscles as well as the kinematic data would provide a more comprehensive analysis of the effect of ICI in patients with knee arthritis.

Results

The results of this study are presented in the form of two manuscripts. The first manuscript describes the effect of ICI on kinematic changes during gait, whereas the

second manuscript describes pain and functional changes following ICI. Most of the participants had difficulty finishing all five trials of step and stairs during the pre-injection session. Hence, the kinematic analysis was not performed for step/stair climbing in the participants and their ability to use step and /or stairs was analyzed as a functional outcome following ICI. The ability to use the step and/or stairs was assessed using a scale of 0 to 10, where 0 was inability to use both steps and stairs and 10 was ability to use steps and stairs for at least five trials each for step and stairs.

TABLE

Table 1. Participant Characteristics

Parameter	Mean ± SD
Age (years) (N = 8)	43.9 ± 12.9
Gender (M/F)	0/8
Disease Duration (years) (N = 6)	8.7 ± 7.8
Joint Count (N = 6)	
Swollen	2.3 ± 2.2
Tender	3.2 ± 5.4
Both	2.7 ± 3.2

Manuscript 1

Kinematic Analysis during Gait following Intra-articular Corticosteroid Injection in Knee joint with an Acute Exacerbation of Arthritis

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Keywords: Vicon, GAITRite®, Gait, Kinematics, Intraarticular Corticosteroid Injection, Knee Arthritis

INTRODUCTION

The prevalence of knee arthritis is increasing due to the aging population in Canada. Pain, local joint swelling, stiffness, and difficulties with activities of daily living (ADLs) are the main symptoms of OA knee. Pain related to knee arthritis leads to altered movement and muscle activation patterns during gait (Childs et al. 2004). Intraarticular corticosteroid injections (ICI) are often administered to reduce pain in patients with acute exacerbation of knee pain in rheumatoid arthritis of the knee (Lundberg et al., 2004; Raynauld et al., 2003), OA of the knee (Tang et al., 2005; Shrader et al., 2004; Hassan et al., 2002), JIA (Brostrom et al., 2004). The improvement in knee pain is expected to improve gait pattern and functions. Physiotherapists frequently treat patients suffering from knee arthritis. Goals of physiotherapy treatment include optimizing movement and strength, and reduce pain. Hence, it is important for physiotherapists to have clear understanding of alterations in lower limb movements in patients with knee arthritis. Changes in lower limb movement patterns following ICI in the patients with knee arthritis have begun to be examined. Several researchers have attempted to objectively measure changes in lower limb movements during gait following ICI in patients suffering from knee arthritis (Shrader et al., 2004; Brostrom et al., 2004)

Changes in gait patterns have been observed in patients with knee arthritis. Literature also suggests changes in muscle activation pattern in presence of knee arthritis during gait. These alterations help them to reduce pain during ambulation (Childs et al., 2004; Al Zahrani et al., 2002; Hinman et al., 2002). Previous studies measured kinematics and muscle strength in patients with knee arthritis following pain relieving interventions. Concentric and eccentric knee muscle strength was found to be

significantly improved following intraarticular knee injections of hyaluronan in patients with knee arthritis (Tang et al., 2005). Intraarticular injection of bupivacaine also improved maximum voluntary contraction of quadriceps in knee arthritis patients (Hassan et al., 2002). Knee joint kinematics were improved in knee arthritis patients after high tibial osteotomy (Takemae et al., 2006) and medial compartment osteotomy (Webster et al., 2003).

Alterations in gait kinematics following ICI in knee arthritis have also been measured in past. Lower limb joint movements and gait characteristics have been found to improve following ICI in knee arthritis. Shrader et al (2004) used a 3D motion analysis system to measure the immediate effect of ICI on joint kinematics during gait and stair climbing in adults with knee arthritis before and fifteen minutes after ICI in the affected knee joint. No significant differences were observed in any of the joint angles at the hip, knee, or ankle during gait. However, gait velocity and cadence were found to be significantly increased following ICI. The study measured the immediate effect of ICI on joint kinematics (Shrader et al., 2004). In another study, changes in gait pattern were investigated following ICI in lower extremity joints in children with juvenile idiopathic arthritis (JIA). The gait kinematics were measured before ICI and 8-17 days later. The knee and ankle joint range and walking velocity significantly increased following ICI. The study demonstrated a short-term effect of ICI in the kinematics of lower extremity joints in children with JIA (Brostrom et al., 2004). In a study that demonstrates the long-term effect of knee injection, Tang et al (2004) measured changes in sagittal ground reaction forces and gait patterns following intraarticular hyaluronate injections in knee

arthritis patients. Significant improvement in sagittal ground reaction force and gait pattern was observed which lasted for over six months (Tang et al., 2004).

The literature supports the use of ICI for improving lower limb kinematics and gait patterns in patients with knee arthritis. However, there are studies that advocate avoiding weight bearing for 24 hours post-injection to maximize the effect of ICI (Chakravarty et al., 1994). The immediate effect of ICI on kinematics as shown by Shrader et al (2004) may not represent a true comparison pre- and post-ICI. Brostrom et al (2004) took this into account and measured the kinematics 8-17 days following ICI. Their study represents the effect of ICI on the kinematics in several lower extremity joints in a pediatric age group. Hence, the study findings cannot be applied to an adult population. The study performed by Tang et al (2004) mostly represents changes in ground reaction force and loading responses following ICI in knee arthritis.

Detailed comparisons of lower limb kinematics during gait and stair climbing following ICI in arthritic knee have not been done. The current study measured lower limb joint movements in adult patients with knee arthritis and the effect of ICI on alterations in these movements.

PURPOSE

The purpose of this study was to compare lower limb joint movements on the injected side during gait and stair climbing in patients with knee arthritis pre- and post-ICI in the inflamed knee joint. The study also aimed to measure spatiotemporal gait parameters in participants. The specific objectives included comparison of movement excursions for ipsilateral knee flexion/extension (flex/ext), ankle dorsi flexion/plantar

flexion (DF/PF), and hip abduction/adduction (abd/add) angles during the stance phase of gait and spatiotemporal gait parameters such as cadence, velocity, bilateral stride length, bilateral step length, step width, bilateral step time, double support percentage, and ipsilateral single support percentage pre- and post-ICI.

HYPOTHESES

It was hypothesized that the movement excursions for ipsilateral knee flex/ext would improve during gait following ICI in patients with acute exacerbation of knee arthritis. Also, the spatiotemporal gait parameters such as cadence, velocity, bilateral stride length, bilateral step length, step width, bilateral step time, double support percentage, and ipsilateral single support percentage were expected to improve following ICI.

METHODS AND MATERIALS

Participants

Nine participants (all females) suffering from exacerbation of rheumatoid arthritis of the knee joint were recruited for the study. The exclusion criteria included previous history of neurological or musculoskeletal condition affecting gait, muscle contracture or deformity in lower limb or spine, multiple joint arthritis in lower limbs, and use of external aid for ambulation. A research nurse discussed study details with each participant and then participants gave written consent to participate in the study. Table 1 illustrates the characteristics of the study population. The study was approved by the University of Manitoba Health Research Ethics Board (H2005: 137).

Instrumentation

A Vicon Motion Analysis system (Oxford, UK) was used for kinematic data capture. The University of Manitoba Pain Research Laboratory has a 6-camera Vicon system that captures kinematic data at a frequency of 120 Hz. The system tracks the x, y, z coordinates of the markers attached to pre-defined areas of the body. The Vicon Plug-in Gait software allows extraction of joints angles into ASCII format for further analysis.

Spatiotemporal parameters were obtained using a GAITRite® (CIR Systems Inc. Clifton, NJ 07012) system. The GAITRite® carpet is embedded with sensors and it records footfalls as a participant walks over the carpet. The GAITRite® software processes these footfall patterns and computes spatial and temporal parameters.

Body height and leg length were measured using a measuring tape. Bilateral knee and ankle joint circumference were measured using joint calipers. These measurements are necessary for the Vicon and GAITRite® systems in order to compute joint angles and spatiotemporal parameters. Also, 100 mm vertical Visual Analogue Scale (VAS) was used for measuring pain intensity in participants pre- and post-ICI. The anchors of VAS were 'no pain' and 'pain as bad as it can be.

Study Protocol

Once participants agreed to participate in the study at the Health Science Centre Rheumatology Clinic, they attended the Pain Research Laboratory for a primary data collection session. VAS score, ROM for both the knee joints and anthropometric characteristics such as leg length, body height, body weight, knee, and ankle joint girth were obtained before the kinematic data collection. The Vicon and GAITRite® systems

were prepared and calibrated for data collection. The GAITRite® carpet was positioned in the capture area of the Vicon system, so that kinematic and spatiotemporal parameters could be obtained simultaneously. The anthropometric characteristics for each participant were entered into the Vicon and GAITRite® system.

Participants were instructed to wear shorts and comfortable walking shoes for the data collection session. Reflective markers were attached bilaterally to upper and lower limbs, and the spine and thorax at pre-defined anatomic locations using the Vicon Plug-in Gait model as shown in figure 1. Participants were given one practice gait trial to get accustomed to the capture area. They were advised to walk at their normal self-selected pace. For each trial, participants walked approximately for eight meters. The Vicon and GAITRite® systems were triggered simultaneously as participants entered the capture area and stopped as they walked out of the capture area. After each gait trial, a scan of the trial was performed to ensure that the trial was comprehensive and yielded sufficient data. Five successful gait trials were obtained for each participant in one session.

After the initial data collection session, participants returned to the Rheumatology Clinic for ICI in the affected knee joint. Participants returned to the Pain Research Laboratory for the follow-up data collection session within 7-10 days. The same data clinic collection procedures were repeated at that time.

DATA ANALYSIS

Out of nine participants that were tested before they had ICI, one participant was unable to return for the follow-up assessment a week later. Data for eight participants was available for analysis and compared pre- and post-ICI. Kinematic data was initially

conditioned within Vicon software. The gait trials were scanned manually to ensure that the data was continuous. Up to six missing data points were filled using the Vicon software. Bilateral hip, knee, ankle, and spine angles were exported in ASCII format. Bilateral ankle and heel marker trajectories were also exported.

The ASCII files were processed using custom scripts in MatLab v 7.1 (The MathWorks Inc., Natick, MA, USA). The software separated each gait cycle into swing and stance phases using the 'z' coordinates of ankle and heel trajectories. The number of stance phases varied between pre- and post-ICI sessions for each participant. Based on the number of stance phases each participant was able to take post-ICI, the same number of stance phases were used to compare from the pre-ICI session. Care was taken to ensure that at least one stance phase was extracted from each trial for comparison. Five to eight stance phases were extracted from the five walking trials in each participant for each session. The outcome variables that were analyzed included ipsilateral knee flex/ext, ankle DF/PF, and hip abd/add angles during the stance phase within each participant. Each stance phase was offset to start at zero by subtracting the column from the average value of the first five data points. The average stance phase for each variable was obtained for each session and compared within each participant and also for group pre- and post-ICI. Pre- and post-injection comparisons were made for the first sixty data points for each variable, which represented approximately 85% of stance phase. Peak joint angles for ipsilateral hip adduction, ankle DF and PF, and knee flexion were averaged for each participant and compared as a group pre- and post-ICI.

The GAITRite® data included ten gait cycles per session for each participant. Cadence, velocity, bilateral stride length, bilateral step length, step width, bilateral step

time, double support percentage, and ipsilateral single support percentage were selected for comparison. Mean values for these variables were compared between the participants pre- and post-ICI.

The VAS score was calculated by measuring the distance (mm) from zero to the mark the participant made indicating pain intensity. An average score for all the participants was obtained for pre- and post-ICI sessions. Percentage change in VAS was calculated to look at the relationship between pain and peak knee flexion angles.

STASTICAL ANALYSIS

Paired t-tests were performed for each data point on the stance phase for a variable. The advantage of point-to-point t-test is that it shows differences at various stages of stance phase and identifies change in the pattern of movement. Sixty paired t-tests were performed to identify regions of difference over the entire stance phase. Since there are 60 inferential tests (a paired t-test at each joint angle over sixty data points), the chances of Type I error are greater. In order to effectively counter a Type I error two strategies were implemented. First, the level of significance was accepted at $p<0.01$ while comparing the excursion of lower limb joint angles during stance phase. Also, a technique was adopted to only accept trends in data that occurred over three consecutive points as compared to accepting any single comparison showing a significant result at an individual joint angle. This method of analysis is based on a mathematical probability model where the likelihood of having three consecutive random type 1 errors is less than 0.01. The technique not only counters against Type I errors, but it also guards against

Type II errors and it has been employed in past for similar comparisons (Hodges, 2006; Hiemstra et al., 2000).

Peak joint angles and mean values for spatiotemporal parameters and VAS were also compared using paired t-test. Wilcoxon Signed Rank Test was used if the normality test failed. Pearson correlation test was used for comparing the relationship between percentage change in VAS and peak knee flexion angle. Sigma Stat V.3.1 software (SPSS, Chicago, IL) was used for statistical analyses. Statistically significant difference was considered at $p<0.05$ for peak joint angles, spatiotemporal gait parameters, and VAS.

RESULTS

Comparison of Kinematic Parameters – Group

Figure 2 demonstrates ipsilateral knee flex/ext, ankle DF/PF, and hip abd/add angles for group. As observed, there is a clear trend suggesting increased excursion in all the movements following ICI. Peak values for hip adduction and ankle DF were not significant post-ICI, but peak values for knee flexion and ankle PF angles increased significantly following ICI in participants ($p<0.05$) as shown in the figure. However, the movement excursions were not significant when compared between the participants as a group. There was a weak correlation between pain and change in peak knee flexion angles ($p>0.05$). Results are also described separately for each kinematic variable for a representative participant.

Comparison of Kinematic Parameters – Representative Participant

Figure 3A demonstrates ipsilateral knee flex/ext angles during stance phase pre- and post-ICI in a representative participant. The excursion in knee flexion increased throughout the stance phase following ICI. However, the differences were significant during the mid-stance phase only ($p<0.01$). Figure 3B shows the p-values plot obtained from pre- and post-ICI comparison ($p<0.01$). As clearly seen, differences were significant between 150 milliseconds to 350 milliseconds during the stance phase.

Figure 4A demonstrates ipsilateral ankle DF/PF angles during stance phase pre- and post-ICI. The plantar flexion angle increased during the initial stance and dorsi flexion angle increased during the late stance phase. However, differences were significant only in the late stance indicated by the grey shaded area between 460-500 ms where dorsi flexion increased following ICI ($p<0.01$).

Figure 4B demonstrates ipsilateral hip abd/add angles during stance phase pre- and post-ICI in the representative participant. Reduced movement in hip abduction and increased hip adduction was observed following ICI. However, the differences were not significant during the stance phase ($p>0.01$).

Spatiotemporal Parameters

Spatiotemporal gait parameters were compared for the group and the results are described as mean ± standard deviation or median (interquartile range) for pre- and post-ICI sessions. Table 2 summarizes results and p values obtained from the comparison of spatiotemporal parameters.

The parameters that showed significant improvement were cadence, velocity, bilateral stride length, bilateral step length, and step width ($p \leq 0.02$). This suggested that the participants were able to ambulate faster and cover more distance in the same number of trials following ICI.

For the temporal parameters, ipsilateral step time and double support percentage reduced significantly in the post-ICI session ($p \leq 0.02$). However, contralateral step time and ipsilateral single support percentage remained unchanged following ICI. Thus, participants took less time to take steps on the affected side, but there was no significant change for the same on the opposite side. Percentage of time spent in single support during the gait cycle remained unchanged as well for the affected side.

Overall, spatiotemporal gait parameters showed improvement following ICI.

Visual Analogue Score

Mean values for VAS were compared for pre-injection and post-injection sessions for all the participants. Paired t-tests showed significant reduction in VAS (from 65 ± 7.89 mm to 31.2 ± 9.18 mm, $p = 0.003$), suggesting improvement in pain level following ICI.

DISCUSSION

The current study attempted to measure changes in kinematics of the ipsilateral lower limb during level walking along with spatiotemporal gait parameters following ICI in patients with acute exacerbation of rheumatoid arthritis of the knee. We hypothesized

that the movement excursion and spatiotemporal gait parameters would improve following ICI in the affected knee joint.

Even though there was no intentional gender bias in the study, all the participants that were recruited were female. Interestingly, previous studies have shown that the impact of arthritis, overall pain experience and activity limitations have been found to be greater in females than their male counterparts (Theis, Murphy, Hootman, Helmick, & Yelin, 2007; Hootman, Sniezek, & Helmick, 2002; Felson et al., 1997). So, even though the results may not be generalized to include males, they were reflective of the female population.

Movement excursions were not significant when compared in participants as a group. This could be due to the fact that the participants varied significantly in their age, body height, body weight, and severity of their disease. A recent study has demonstrated that the gait pattern differs in patients with knee arthritis severity (Astephen, Deluzio, Caldwell, & Dunbar, 2008; Astephen, Deluzio, Caldwell, Dunbar, & Hubley-Kozey, 2008). Also, the number of participants involved in the study was eight and a larger number of participants would have reduced the inherent variability. Participants had swelling and tenderness in other lower limb joints as well suggested by the joint counts, but primary reason for their visit to the Rheumatology Clinic was acute knee pain.

In the ipsilateral lower limb movements, the change in knee joint movement was the most significant compared to other lower limb joint angles. The overall excursion into knee flexion increased significantly as well as the peak flexion angle, which is consistent with previous study that measured the similar change following ICI (Brostrom et al., 2004). It has been shown in the past that deceased range of motion at the knee during

stance is a response to arthritic pain and related disability. It is a strategy to stabilize the painful knee joint and reduce extensor moments to avoid compressive forces (Maly, Costigan, & Olney, 2006; Childs, Sparto, Fitzgerald, Bizzini, & Irrgang, 2004; Kaufman, Hughes, Morrey, Morrey, & An, 2001). Improved knee joint movement during stance can be explained in part by the reduced pain intensity observed in participants as result of ICI in the current study. The knee flexion angle at initial contact of stance in the group decreased from 14 ± 5.7 to 11.4 ± 5.9 degrees, $p<0.02$ following ICI. Statistically this change was not significant and post-ICI knee flexion at heel-strike was still greater than what other studies have reported in arthritis patient groups (Childs et al., 2004; Webster et al., 2003). This indicates that the participants in this study landed on the ground with their knee flexed even after ICI, which is a feature that is common in knee arthritis. The correlation between the change in VAS and peak knee flexion angle was also weak and insignificant. Ankle dorsi flexion angles increased as well during the late stance phase following ICI. The changes were significant in movement excursion. This change is likely due to increased knee flexion reported during this phase that causes forward translation of tibia, which results in increased dorsi flexion at ankle. The improvement in knee flexion along with ankle dorsi flexion signifies improved movement synergy during stance. As per our knowledge, no previous studies measured change in hip abd/add angle following ICI. The current study demonstrated that the hip abduction reduced and hip adduction increased as a result following ICI but the change was not significant. Step width reduced significantly post-ICI, which supports the change in hip abd/add angles as participants did not walk with wide base gait post-ICI. In summary, it was observed that

the patients with acute exacerbation of rheumatoid arthritis of the knee demonstrate altered kinematics at knee and ankle joints in sagittal plane.

The abnormality observed in spatiotemporal gait parameters is considered to be the result of pain and reduced movement excursion to guard the joint against pain during stance phase (Bejek, Paroczai, Illyes, & Kiss, 2006; Al Zahrani et al., 2002; Gok, Ergin, & Yavuzer, 2002). Increase in step length can be explained by the improvement in movement excursion at the knee joint following ICI. The current study allowed the participants to walk at their self-selected gait speed. Previous studies have shown that gait velocity is reduced in severe knee arthritis patients due to pain and impaired joint kinematics (Kaufman et al., 2001; Teixeira & Olney, 1996; Mattsson, Olsson, & Brostrom, 1990), however, with moderate knee OA gait velocity is comparable to normal values (Landry, McKean, Hubley-Kozey, Stanish, & Deluzio, 2007; Mundermann, Dyrby, Hurwitz, Sharma, & Andriacchi, 2004). In our study, the average gait velocity for participants following ICI was 102.8 ± 19.1 cm/sec. It increased compared to pre-ICI values but it was still lower than the self-selected gait velocity for control participants of similar age group reported in other studies (Astephen et al., 2008; Su, Gard, Lipschutz, & Kuiken, 2007; Landry et al., 2007; Al Zahrani et al., 2002). Reduced double support percentage suggested that the participants walked faster following ICI and is consistent with increased gait velocity. Ability to walk faster can be an important functional gain, and especially with increased independence in outdoor access, which could potentially enhance overall quality of life.

Cadence also increased in participants following ICI. Improvement in cadence can be attributed to reduced step time, as participants were able to take more steps per

minute after ICI compared to pre-ICI values. Brostrom et al (2004) also reported significantly increased cadence in their study following ICI. The post-ICI cadence in their study was 128 ± 12.3 steps/min, whereas in the present study post-ICI cadence was 107.9 ± 6.6 steps/min. The greater cadence is possible due to the fact that Brostrom et al (2004) recruited children with average age of 10.9 and average height of 141.2 cm compared to the present study where the average age of the participant was 43.9 and average height was 163.31 cm. With longer legs, participants would be able to take comparatively fewer steps.

Contralateral step length increased following ICI, suggesting that the participants could spend more time in stance on the affected side, which allowed the other leg to take a bigger step. In comparison single support percentage remained unchanged following ICI suggesting no change in the amount of time spent on the ipsilateral lower limb during stance.

Changes in spatiotemporal gait parameters such as gait velocity and cadence can be termed as more patient-relevant benefits of ICI. Improvement in these parameters is likely the result of improved knee joint kinematics following ICI.

CONCLUSION

In conclusion, the study demonstrated positive short-term effects of ICI on lower extremity joint kinematics and spatiotemporal gait parameters in patients with an acute exacerbation of rheumatoid arthritis of the knee. The affected knee joint showed the most improvement in movement excursions followed by ankle movements in the sagittal plane. Careful interpretation of the results is necessary because the study involved a small and

exclusively female patient group. Nonetheless, this study provides objective measurements of the outcome of a commonly used intervention in the treatment of acute exacerbation of knee arthritis. The study findings should be used as a reference for future studies measuring the knee joint kinematics and functions following pain relieving interventions in knee arthritis. Future studies should look at the effects of ICI over a longer period and measure the change in lower extremity and spine kinematics. Researchers can also assess muscle contraction pattern and joint kinetics in this patient group following ICI, which would provide a more comprehensive explanation of the benefits of ICI in patients with knee arthritis.

It is common for physiotherapists to treat patients with knee arthritis who undergo ICI for knee pain while receiving physiotherapy treatment. These results help physiotherapists to understand the effect of ICI on the knee joint movements and gait parameters in patients with knee arthritis. Physiotherapists will be able to design more precise exercise routines for such patient groups that can maintain ROM and enhance functional ability.

Figure 2. Lower Limb Joint Angles - Group

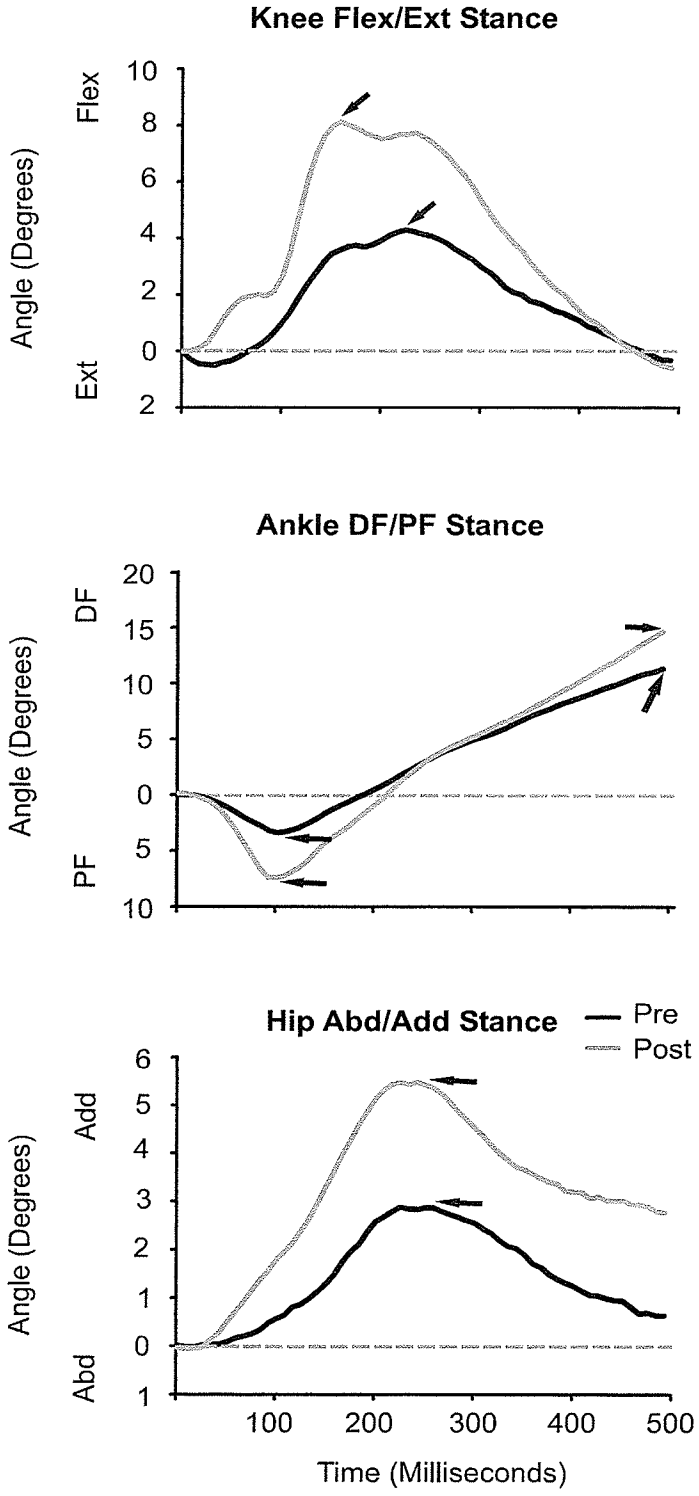

Figure 3. Ipsilateral Knee Flex/Ext Angles – Representative Participant

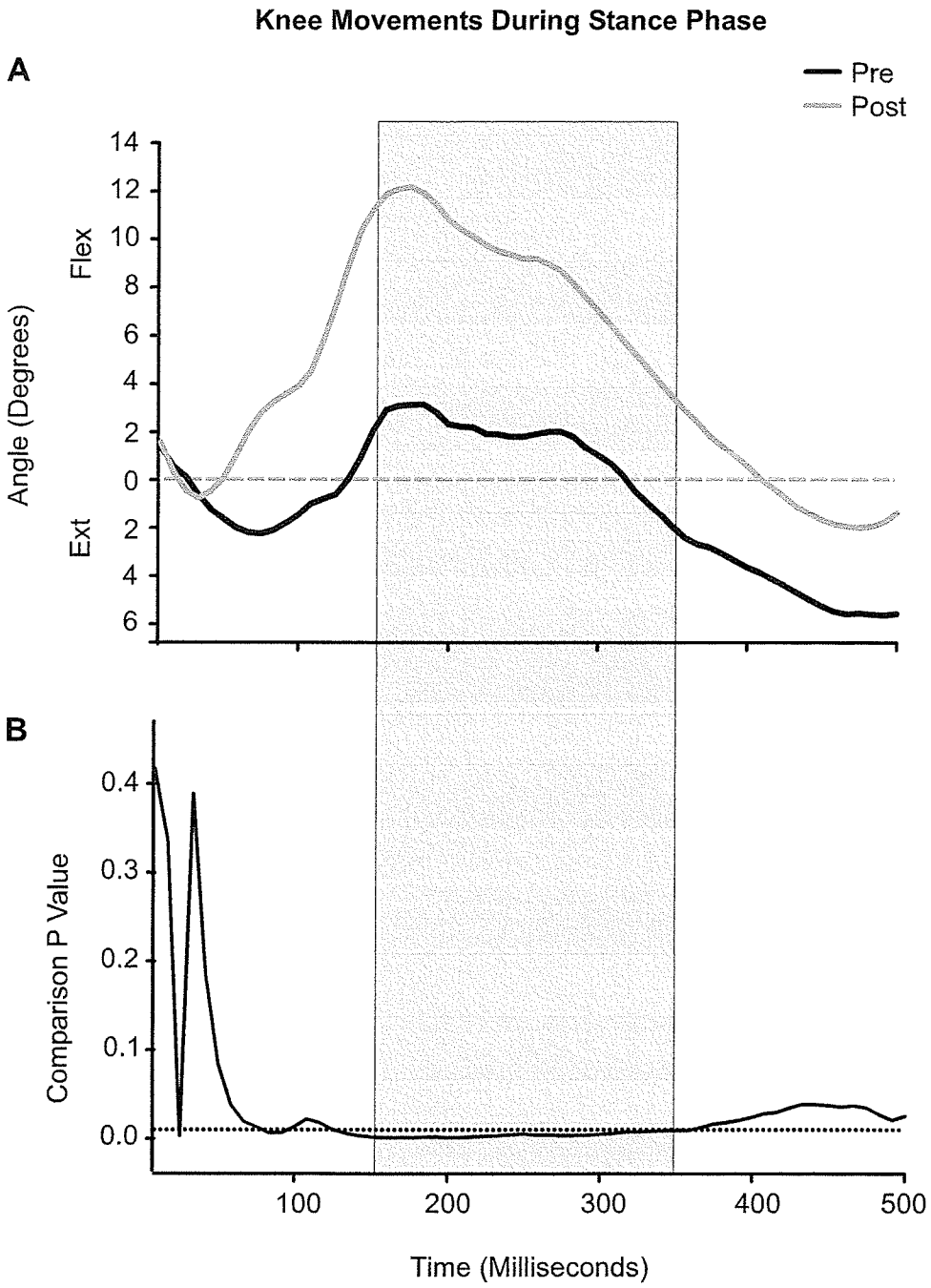

Figure 4. Ipsilateral Ankle DF/PF and Hip Abd/Add Angles – Representative Participant

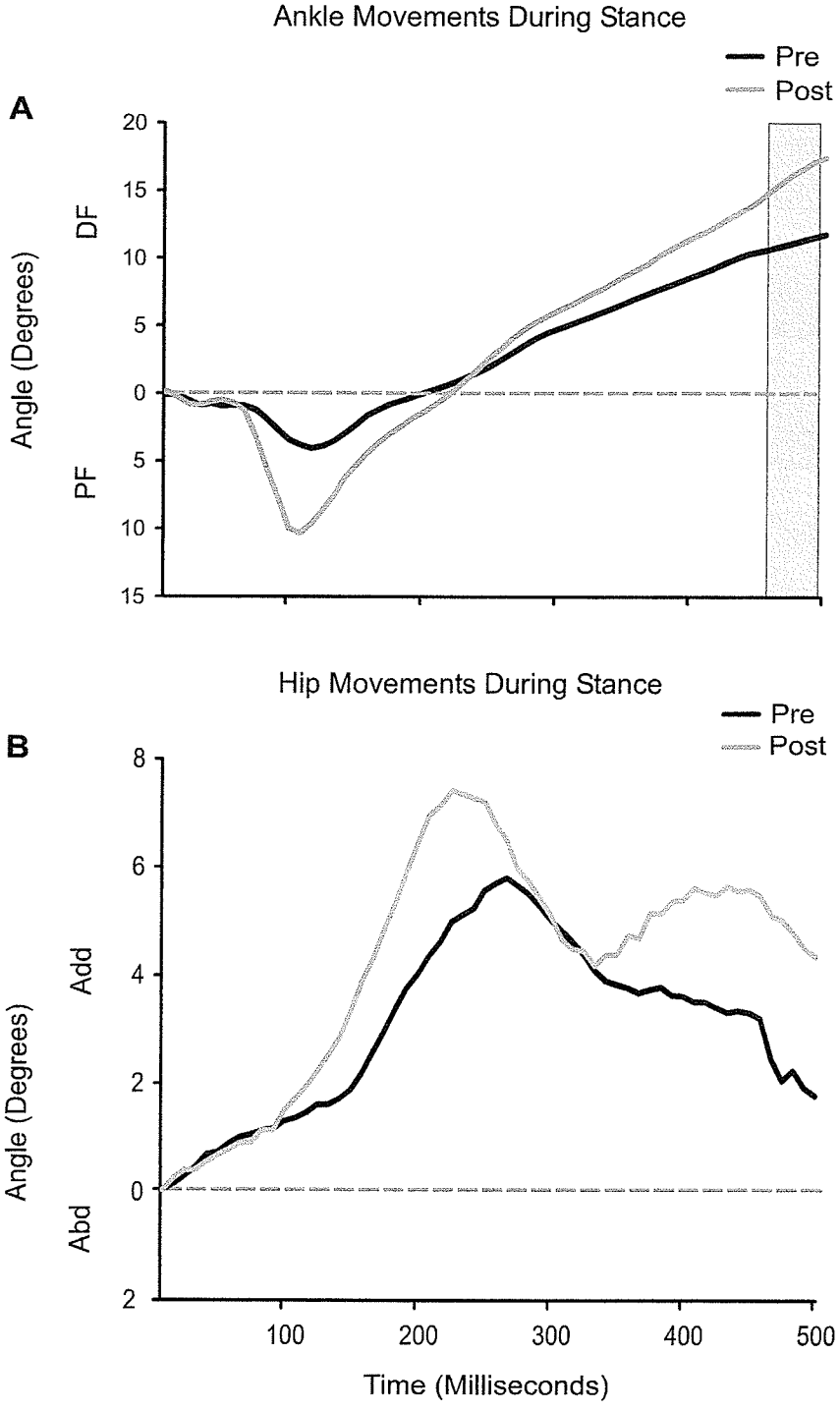

FIGURE LEGENDS

Figure 2. Ipsilateral Knee Flex/Ext, Ankle DF/PF, and Hip Abd/Add Angles During Stance Phase For All the Participants

These graphs demonstrate the average knee flex/ext, ankle dorsi/plantar flexion, and hip abd/add angles during stance phase for all the participants (N = 8) pre- and post-ICI. Time is expressed in milliseconds along the x-axis and joint angles in degrees are represented along the y-axis. Peak angles, indicated by the arrows, are described for each curve with mean ± SD. The graphs clearly reflect the trend of increased excursion in knee flexion, hip adduction, and ankle DF/PF movements during stance phase following ICI. However, the change was not significant in any of the movements. Peak angles significantly increased for knee flexion (5.6 ± 2.7 to 8.5 ± 3.4; $p < 0.03$) and ankle PF during stance phase (5.0 ± 2.2 to 8. 6 ± 3.6; $p<0.05$) following ICI (*Significant, $p<0.05$). Peak angles for ankle DF (11.5 ± 5.7 to 14.8 ± 6.4; $p>0.05$) and hip adduction (4.4 ± 2.6 to 5.9 ± 3.5; $p>0.05$) increased following ICI, however the change was not significant.

Figure 3. Ipsilateral Knee Flexion Angle During Stance Phase in a Representative Participant

These graphs demonstrate change in knee flex/ext angle pre- and post-ICI in a representative participant. Figure 3A shows ipsilateral knee flex/ext angle during stance phase pre- and post-ICI. Time is expressed in milliseconds along the x-axis and joint angles in degrees are represented along the y-axis. The graph shows that excursion into knee flexion was significantly increased during 150 ms to 350 ms post-ICI described by the grey shaded area (Point-to-point paired t-test; $p<0.01$).

Figure 3B shows graph of p-values obtained from the comparison of pre- and post-ICI knee flex/ext angles during stance phase. The pre- and post-ICI angle are considered significantly different, when $p<0.01$ for 3 consecutive data points as shown by the shaded area.

Figure 4. Ipsilateral Ankle DF/PF and Hip Abd/Add Angles During Stance Phase in the Representative Participant

These graphs demonstrate ankle dorsi/plantar flexion and hip abd/add angles during stance phase for representative participant pre- and post-ICI. Figure 4A shows that the excursion into ankle dorsi flexion significantly increased from 460 ms to 500 ms post-ICI as described by the grey shaded area (Point-to-point paired t-test; $p<0.01$). Figure 4B shows that the comparison in hip abd/add angles remained insignificant throughout the stance phase post-ICI (Point-to-point paired t-test; NS).

TABLE

Table 2. Spatiotemporal Parameters

Spatiotemporal Parameter	Mean ± SD Score or Median (IQR) Pre-Injection	Mean ± SD Score Median (IQR) Post-Injection	P Value
Cadence (steps/min)	101.5 ± 6.6	107.9 ± 6.6	0.005
Velocity (cm/sec)	79.5 ± 20.4	102.8 ± 19.1	0.005
Ipsilateral Single Support Percentage	33.1 ± 5.45	36.1 ± 1.71	0.09
Ipsilateral Double Support Percentage	30.2 (29.3 - 30.85)	29.3 (28.3 – 29.8)	0.008
Ipsilateral Stride Length (cm)	94.1 ± 22.3	114.2 ± 15.9	0.019
Contralateral Stride Length (cm)	93.8 (81.9 – 115.5)	114.9 (100.7 – 126.9)	0.016
Step Width (cm)	12.9 ± 2.37	10.1 ± 2.9	0.005
Ipsilateral Step Time (seconds)	0.6 ± 0.05	0.56 ± 0.02	0.015
Contralateral Step Time (seconds)	0.58 ± 0.04	0.56 ± 0.04	0.163
Contralateral Step Length (cm)	46.0 (39.4 – 56.5)	58.8 (51.4 – 63.9)	0.008
Ipsilateral Step Length (cm)	49.4 (39.6 – 56.4)	55.6 (48.6 – 63.1)	0.016

TABLE LEGENDS

Table 2. Spatiotemporal Parameters

This table summarizes spatiotemporal parameters that were compared in participants pre- and post-ICI. The scores are described as mean ± SD for each variable. The normality test failed for ipsilateral double support percentage, contralateral stride length, contralateral step length, and ipsilateral step length and Wilcoxon Signed Rank Test was used. The results are described as median values pre- and post-ICI for these parameters.

Manuscript 2

Pain and Functional Analysis following Intra-articular Corticosteroid Injection in Knee joint with Acute Exacerbation of Arthritis

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Keywords: VAS, KOOS, Intra-articular Corticosteroid Injection, Knee Arthritis

INTRODUCTION

Joint arthritis has been identified as one of the most common chronic diseases affecting older adults. A report by Health Canada estimates that by the year 2026, six million Canadians older than 15 years of age will have arthritis (Health Canada, *Arthritis in Canada. An ongoing challenge.* Ottawa: Health Canada 2003). The costs related to arthritis in Canada are substantial and likely underestimated (Gupta et al., 2005).

Knee joint arthritis is commonly observed in older adults. Pain, joint effusion, stiffness, and difficulties in ADL are common to knee arthritis. Alterations in lower limb movement patterns have been observed during gait and step climbing in patients with knee arthritis, which in turn is likely to contribute to disease progression (Childs et al 2004). Spatiotemporal gait parameters such as cadence, stance time, and stride length have also found to be altered in subjects with knee arthritis (Al Zahrani et al., 2002).

The impact of arthritis related disability on various aspects of daily living at home and work has been found to be significant (Fautrel et al., 2005). Pain due to exacerbation of knee arthritis contributes to difficulties at ADL and impairs quality of life. Several studies have indicated poor quality of life and the disabling impact of the disease in patients with knee arthritis. Health-related quality of life (HRQOL) was compared in patients with lower limb arthritis and healthy controls in one study. HRQOL was measured using the SF-36 questionnaire, which includes functional aspects of well-being such as physical functioning, limitations due to physical problems, bodily pain, energy level, role limitations due to emotional or personal problems, mental health, social functioning, and general health perception. The study concluded that older adults with OA of the lower extremities display significant impacts on multiple dimensions of

HRQOL, compared with healthy controls (Salaffi, Carotti, Stancati, & Grassi, 2005). Song et al (2006) also demonstrated higher incidence of disability in patients with arthritis.

Conservative pharmacological treatment for knee arthritis may include oral or transdermal NSAIDS, or intraarticular injections (Barron & Rubin, 2007; Raynauld et al., 2003). Improvement in functional status and pain relief are the main objectives for most interventions relating to arthritis. The change in functional status and pain intensity have been measured in the past using standardized assessment tools such as the Knee injury and Osteoarthritis Outcome Score (KOOS). The KOOS has been used in recent past as an alternative for measuring patient-relevant effects in the treatment of knee arthritis (Rastogi, Davis, & Chesworth, 2007; Krocker et al., 2006). The KOOS is an extension of the WOMAC and has two additional subscales: sports and recreation and knee related quality of life.

There is evidence to suggest positive effects of intraarticular corticosteroid therapy in patients with knee arthritis. Intraarticular knee joint injection of sodium hyaluronate significantly improved functional status as suggested by the change in Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (Turajane, Tanavaree, Labpiboonpong, & Maungsiri, 2007). In another study, intraarticular injections of hyaluronan with/without corticosteroid were administered in patients with knee osteoarthritis. Participants received a series of intraarticular injections over the period of one year. Visual Analogue Scale (VAS) and WOMAC were measured at baseline and at months 1–3, 6, 7, 9, and 12. The patient group treated with intraarticular injections of hyaluronan with corticosteroid showed marginally better results with

WOMAC and VAS compared to intraarticular injections of hyaluronan alone. However, both the groups had significant improvement in functions and pain following intraarticular corticosteroid injection. These studies demonstrate the use of WOMAC and VAS in assessing functions and pain intensity in patients with knee arthritis following intraarticular injections. No study has taken detailed account of pain and functional status including ability to use step/stairs.

PURPOSE

The objective of the current study was to compare pain intensity (VAS), change in functional status (KOOS), and knee girth following intraarticular corticosteroid injection (ICI) in patients with knee arthritis. The other objective was to assess the ability for participants to use stairs or a step following ICI.

HYPOTHESES

It was hypothesized that the functional status and pain intensity would significantly improve following ICI in patients with knee arthritis. Also, the ability to use a step or stairs would improve in participants.

METHODS AND MATERIALS

Nine participants (all females) suffering from exacerbation of rheumatoid arthritis of the knee joint were recruited for the study. The participants were excluded from the study if they had any neurological or musculoskeletal condition that could affect their ability to walk. Participants with acute flare-up in multiple lower limb joints, requiring

the use of assistive device for ambulation, and having muscle contracture or deformity in lower limbs or spine were also excluded from the study. Participants were identified at the Health Science Centre Rheumatology Clinic, Winnipeg, Manitoba, as they attended the clinic for exacerbation of rheumatoid arthritis of the knee. A research nurse discussed the study details with the participants and they indicated interest to participate in the study. The purpose and study details were explained to the participants a written consent was obtained. Table 1 illustrates the characteristics of the study population. The ethics approval for the study was obtained from the University of Manitoba Health Research Ethics Board (H2005: 137).

Instrumentation

Pain intensity was measured using the VAS. VAS measured average pain intensity over the past 24 hours. It has 100 mm vertical line with the anchors of 'no pain' and 'pain as bad as it can be'. Previous studies have shown VAS to be a reliable and valid tool for measuring pain intensity (Summers 2001; Tiplady et al., 1998; Dixon et al., 1981; Scott et al., 1979).

The KOOS was used for measuring the functional status in participants. The KOOS is a patient-relevant 42 item self-explanatory and self-administered questionnaire with five subscales including pain, other symptoms, functions in daily living, sport and recreation function, and knee-related Quality of Life. The KOOS has been validated for use in patients with OA knee (Roos et al 2003; Xie et al 2006).

Additionally, knee and ankle joint girth were measured using a joint caliper. The knee joint girth was measured at the knee joint line and the ankle joint girth was measured across the media and lateral malleoli.

Participants were also assessed with respect to their ability to use the stairs or step. They were graded on a scale of 0 to 10, where 0 was complete inability to use steps and stairs and 10 was ability to use steps and stairs for at least five repetitions each. The scoring system is shown in Table 3.

Procedure

Participants came to the Pain Research Laboratory at the School of Medical Rehabilitation and were asked to wear shorts and comfortable running/walking shoes for the initial data collection session. Leg length was measured using a measuring tape with participants in supine position on a treatment table. Knee joint girth was measured bilaterally in this position as well using joint caliper. Anthropometric measurements (height, weight, leg length, and girth) were measured (see Appendix B, participant information form).

Participants answered the KOOS questionnaire. They were advised to answer the questions based on their experience over the past one week. A VAS for pain was also measured, where participants rated their knee pain over the past 24 hours. Participants marked a point on the scale that best described their pain intensity.

To give an objective indication of functional status, participants attempted to use stairs and steps if able within the limitation of their knee pain. They were expected to try five trials each for step and stairs. However, they could stop anytime if their knee pain

did not allow them and the number of successful trials completed were considered for analysis. Participants returned to the Rheumatology Clinic for ICI into their painful knee joint. They returned to the Pain Research Laboratory 7-10 days later for the follow-up session. The same procedure for data collection was repeated at that time.

DATA ANALYSIS

Out of nine participants that were tested before they had ICI, one participant was unable to return for the follow-up assessment a week later. Data for eight participants was available for analysis and compared pre- and post-ICI. The VAS score was calculated by measuring the distance (mm) from zero to the mark the participant made indicating pain intensity. An average score for all the participants (N = 8) was obtained for pre- and post-ICI sessions. Similarly, knee girth was obtained (cm) for the affected knee joint and average scores were calculated for the participants pre- and post-ICI.

KOOS scores were normalized according to standard procedure and calculated separately for each subscale in a participant. In order to obtain normalized scores for each subscale, the total score of that subscale was divided by the possible maximum score for that subscale (Roos, Roos, Lohmander, Ekdahl, & Beynnon, 1998). The normalized scores were compared between the participants for each subscale before and after the ICI. Gait velocity and cadence were averaged for all the participants as well and compared pre- and post-ICI. Percentage change for VAS scores weas obtained to examine the relationship of pain with QOL and ADL subscales.

Participants were scored on the ability to perform steps and stairs (see table 3). Individual scores were normalized to the maximum obtainable score. For example, a

participant who was able to perform two trials of the single step and no stairs prior to the ICI would be assigned a score of 8. Post-ICI, if the participant was able to perform all five single steps and all five trials of the stairs, she would be assigned a score of 0. The raw scores are normalized to the maximum possible score. A normalized score of 0 indicates no difficulty and 100 indicates extreme difficulty.

$$\text{Normalized percentage} = \text{Maximum percent possible} - \frac{\text{raw score (100\%)}}{\text{Maximum possible raw score}}$$

Calculation Example – raw score pre is 8 and raw score post is 0.

Pre $100-\frac{8(100)}{10} = 20$

Post $100-\frac{0(100)}{10} = 100$

Statistical Analysis

Paired t-tests were used for comparing both the VAS and knee girth measurements pre and post-ICI. Paired t-tests were also computed for comparing step and stair function, and KOOS subscales. However, since the test for normality failed for the Quality of Life subscale (QOL), the non-parametric equivalent Wilcoxon Signed Rank Test was used to analyze these differences. Pearson correlation test was used for examining the relationship between change in VAS and change in QOL and ADL subscales. Sigma Stat V.3.1 (SPSS, Chicago, IL, USA) software was used for conducting statistical analyses. Results with $p<0.05$ were considered significant.

RESULTS

Visual Analogue Scale

The change in pain intensity following ICI was measured by comparing scores on the VAS. Mean values for VAS were compared for pre-injection and post-injection session for all the participants. Pain intensity decreased (65 ± 7.89 mm to 31.2 ± 9.18 mm) indicating overall reduction in pain level following ICI. The results are shown in Table 4.

Knee Osteoarthritis Outcome Score

All five subscales of the KOOS were compared separately to determine subjective improvement in a range of functions. The comparison represents normalized scores averaged for all the participants, where 100 indicates no problems and 0 indicates extreme problems. QOL (12.5 IQR 0 – 21.9 to 34.37 IQR 9.4 – 53.1) and ADL (32.90 ± 19.71 to 70.40 ± 23.45) subscales improved following ICI but the correlations between the change in VAS and QOL and ADL subscales were not significant ($p>0.05$). Pain, symptoms, and sports and recreation showed significant improvement as well and are described in table 3.

Knee Girth

The change in swelling suggests reduction in inflammation. Knee girth reduced following ICI (11.61 ± 0.89 cm to 11.2 ± 0.57 cm), but the change was statistically insignificant.

Functional Ability

The ability to use step/stairs was assessed by rating the performance on a scale of 0 to 10 as described in Table 3. The normalized scores were averaged for all the participants and compared using paired t-tests. The results suggested that participants' ability to use step/stairs increased following ICI (26.25 ± 31.13 to 72.50 ± 31.51, $p<0.05$). Spatiotemporal parameters of gait velocity (79.49 ± 20.47 to 102.81 ± 19.1 cm/sec) and cadence (101.55 ± 6.632 to 107.96 ± 6.62 steps/min) showed significant improvement as well post-ICI. The results are summarized in Table 4.

DISCUSSION

Pain is often the chief concern in a knee arthritis patient and can have disabling effects on knee joint movements and functions. Traditionally, ICI has been a treatment of choice in patients with acute exacerbation of rheumatoid arthritis of the knee. The main objective of the treatment is to control pain and improve functions. In the current study, participants reported reduced pain intensity as suggested by significantly decreased VAS scores. Reduced pain intensity can improve lower extremity joint kinematics (Childs et al., 2004; Kaufman et al., 2001). The current study supports the use of ICI for patients with acute exacerbation of rheumatoid arthritis of the knee as described earlier (Weitoft et al., 2005; Lundberg et al., 2004; Raynauld et al., 2003). Improvement in pain and functional ability is consistent with the previous studies that have reported similar outcomes (Ozturk, Atamaz, Hepguler, Argin, & Arkun, 2006; Raynauld et al., 2003)

Arthritis has been shown to affect ADL and can have disabling impact on daily functions (Machado, Barreto, Passos, & Lima-Costa, 2006; Song, Chang, & Dunlop,

2006). Controlling the disabling effect of arthritic pain and improving ADL can reduce the impact of disease on quality of life. This study measured different aspects of pain-related impairments in patients with acute exacerbation of rheumatoid arthritis of the knee using the KOOS. It has been shown that KOOS subscales "Sport and Recreation function" and "Quality of Life" were more sensitive and discriminative than the WOMAC subscales "Pain", "Stiffness", and "Function" when studied in subjects in patients with knee osteoarthritis (mean 57 years, 38-76) compared to age- and gender matched controls in patients with knee OA (Roos, Roos, & Lohmander, 1999). KOOS has also been used for measuring functional status in other knee pathologies such as anterior cruciate ligament injury (Swirtun & Renstrom, 2008; von Porat, Henriksson, Holmstrom, & Roos, 2007), arthroscopic partial meniscectomy (Katz et al., 2006), patellar fractures (Anand, Hahnel, & Giannoudis, 2008), and total knee replacement (Rastogi, Davis, & Chesworth, 2007). Previous studies have measured general functions following intraarticular injections in knee arthritis using the WOMAC (Juni et al., 2007; Turajane et al., 2007; Ozturk et al., 2006) however, we could find no study which has used the KOOS to measure the effect of intraarticular injection in patients with acute exacerbation of rheumatoid arthritis of the knee. The results of the current study not only indicated improvement in pain perception by the participants, but also a significant change in ADL and QOL as described subjectively by participants. Improvement in the ADL subscale indicates ease in transfers, community ambulation, self-care, and domestic duties. The symptom subscale showed significant improvement as well, which included participants' subjective experience related to symptoms of swelling and knee movements. Improved confidence in knee movements can enhance mobility and activity levels. The

subscale representing sports and recreational activities also showed improvement. Even though most of the participants reported not indulging in sports activities, the subscale did cover functions such as perceived ability to squat, kneel, and pivot the affected knee. Therefore the KOOS appears to be a useful outcome measure to assess functional improvement following ICI in patients with acute exacerbation of rheumatoid arthritis of the knee joint. Lack of correlation between change in VAS and change in QOL and ADL subscales is likely due to smaller participant group.

Swelling in the affected knee joint was reduced following ICI but the change was statistically insignificant. The sample size in this study was smaller and a bigger sample size could have explained the change in swelling more clearly. Patients with acute exacerbation of rheumatoid arthritis of the knee do consider knee swelling as one of their concerns, however, considering improvement in overall functions and activity level, the lack of improvement in knee swelling does not negate the benefits of ICI.

Ability to use a step/stairs is an important aspect of functional mobility. Shrader et al (2004) measured knee joint kinematics, where no improvement was noted in joint kinematics following ICI. The current study showed that overall participants were able to use stairs with less difficulty. Four out of eight participants were not able to perform a step or stairs at all before ICI. Follow-up assessment showed that all the participants were able to complete one step for at least five repetitions. This could be considered an important functional gain with respect to mobility. Most outdoor areas are equipped with alternative arrangements and stair use may not be required. However, negotiating curbs, entering into a house using steps, and accessing multi-levels in the home can be a challenge when pain impairs the ability to use stairs or at least one step. Improvement in

ability to use steps and spatiotemporal parameters such as cadence and velocity (table 4) can markedly increase indoor as well as outdoor mobility in patients with acute exacerbation of rheumatoid arthritis of the knee following ICI.

CONCLUSION

This study looked at the short-term effect of ICI on pain intensity and functions in patients with acute exacerbation of rheumatoid arthritis of the knee. The study used VAS, KOOS, and ability to use step/stairs to measure overall functional status in these patients. The results demonstrated that ICI reduces pain levels and enhances overall mobility and functions. Although originally developed for assessing functions in patients with knee OA, KOOS appears to be a useful tool for assessing functions in patients with rheumatoid arthritis experiencing exacerbation of knee pain and inflammation. Although this study established short-term effects of ICI in patients with acute exacerbation of rheumatoid arthritis of the knee, the long-term effects of ICI are not known. Future studies should assess pain intensity and knee related functions in these patients over a longer period of time.

TABLES

Table 3. Scoring System for Step/Stairs

Score	Number of Trials for Step/Stairs
0	5 Step or 5 Stairs
1	5 Step 4 Stairs
2	5 Step 3 Stairs
3	5 Step 2 Stairs
4	5 Step 1 Stairs
5	5 Step no Stairs
6	4 Step no Stairs
7	3 Step no Stairs
8	2 Step no Stairs
9	1 Step no Stairs
10	No Step no Stairs

Table 4. Pain, Knee Girth, Self-reported Functional Status, and Spatiotemporal Gait Parameters

Parameter	Mean ± SD Score or Median Pre-Injection	Mean ± SD Score or Median Post-Injection	P- Value
KOOS Subscale Pain	32.9 ± 15.5	69.1 ± 23.9	0.005
KOOS Subscale Symptoms	33.0 ± 17.9	65.2 ± 23.9	0.01
KOOS Subscale ADL	32.9 ± 19.7	70.4 ± 23.5	0.002
KOOS Subscale Sports and Recreation	11.4 ± 18.6	44.3 ± 23.2	0.005
KOOS Subscale Quality of Life (QOL)	12.5 (0 – 21.9)	34.37 (9.4 – 53.1)	0.047
Visual Analogue Scale (mm)	65 ± 7.9	31.2 ± 9.2	0.003
Knee Girth (cm)	11.6 ± 0.9	11.2 ± 0.6	0.141
Step/Stairs Score (Normalized Percentage)	26.3 ± 31.1	72.5 ± 31.5	0.005
Cadence (Steps/Min)	101.6 ± 6.6	107.9 ± 6.6	0.005
Velocity (cm/sec)	79.5 ± 20.5	102.8 ± 19.1	0.005

TABLE LEGENDS

Table 3. Scoring System for Step/Stairs

This table shows the scoring system used in the study to assess ability to use steps/stairs in participants.

Table 4. Pain, Knee Girth, Self-reported Functional Status, and Spatiotemporal Gait Parameters

This table highlights the results of KOOS subscales, VAS, Knee girth, and two spatiotemporal parameters (cadence and velocity) that are relevant to the change in functional status. The scores are presented as mean ± SD for pre-and post-ICI sessions. The normality test failed for KOOS subscale of Quality of Life and Wilcoxon Signed Rank Test was subsequently. The results are described as median values (interquartile tange) pre- and post-ICI for this subscale.

APPENDIX A

RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM

Title of Study: **Kinematic Analysis of Bilateral Knee Joints during Gait and Stair Climbing: A Comparative Study before and after Intra-articular Cortisone Injection in Subjects suffering from Acute Flare-up of Knee Arthritis.**

Principal Investigator: **Mr. Saurabh Mehta**
RR 355 – 800 Sherbrook Street, 787-1436

Co-Investigators: **Dr. Barbara Shay**
RR 323 – 800 Sherbrook Street, 787-2756

Dr. Hani El-Gabalawy
RR149, 800 Sherbrook St., 787-2209

You are being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with your friends, family or (if applicable) your doctor before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

Purpose of Study

This research study is being conducted to measure the changes in your knee joint movements during level walking and stair climbing before and after the cortisone injection in your inflamed knee. These measurements will provide important information regarding changes in movement patterns of your both knee joints following a cortisone injection during two important daily functions: walking and stair climbing.

A total of 20 participants will participate in this study.

Study procedures

All participants are being recruited for this study via the Health Sciences Centre Arthritis Clinic. You will be requested to attend two sessions at the University of Manitoba Bannatyne Campus, Pain and Motion Analysis Laboratory, Rehabilitation Hospital, Health Sciences Centre, Winnipeg. Each session will take approximately 30 minutes.

Day of the week and time of day of these sessions will be scheduled to accommodate your schedule.

Data capture will be performed using the VICON Motion Analysis System. You will be asked to walk and also use the stairs in the visual field of the motion cameras. During the trial, you will be expected to wear shorts. The shorts might be taped to prevent the lower end of the shorts covering the thigh markers. You are free to wear a T-shirt but it might need to be moved up slightly and taped in place in order for the cameras to view the pelvis markers. The cameras do not record you, they record only the reflective markers.

Before the walking trial, your body weight and height will be measured. Your knee width, ankle width, and leg length will also be measured on both sides. These measurements will be taken in standing.

Reflective markers (about the size of a pea) will then be attached with tape to your pelvis, thigh, knee, leg, ankle, heel, and toes on both sides. At this stage you will be given practice trials for walking and stair climbing. Following that you will be asked to perform five trials each for stair climbing and walking in the visual field of the cameras at a natural speed. The visual field is about 4 meters long and 1.5 meters wide. Five trials of each activity will be taken on two separate occasions: on the day of injection prior to the injection, and approximately 1 week after the injection. All the trials will be videotaped using the motion analysis video cameras. The video-based motion analysis will automatically track the markers and provide precise information on how your body segments move during the walking and stair climbing trials.

After these procedures, the markers will be removed from your body and the session will end.

The session will be stopped if:

- **You wish to stop for any reason.**
- **You exhibit signs of pain or discomfort.**
- **You feel any problem with your balance.**

The researcher may decide to take you of this study if you are unable to perform the exercise properly (i.e. safely).

You can stop participating at any time. However, if you decide to stop participating in the study, we encourage you to talk to the study staff first.

<u>Risks and Discomforts</u>

Slight discomfort may be experienced while removing tape from your skin that holds the markers in place.

Benefits

There may or may not be direct benefit to you from participating in this study. We hope the information learned from this study will increase the understanding of effects of knee joint cortisone injections on knee joint movements during two important functions of daily living, i.e. walking and stair climbing.

Costs

All the procedures, which will be performed as part of this study, are provided at no cost to you.

Payment for participation

You will receive no payment related to taking part in this study. Parking costs will be re-imbursed.

Confidentiality

Information gathered in this research study may be published or presented in public forums, however your name and other identifying information will not be used or revealed. Despite efforts to keep your personal information confidential, absolute confidentiality cannot be guaranteed. Your personal information may be disclosed if required by law.

The University of Manitoba Health Research Ethics Board may review records related to the study for quality assurance purposes.

All records will be kept in a locked secure area and only those persons identified will have access to these records. If any of your research records need to be copied to any of the above, your name and all identifying information will be removed. No information revealing any personal information such as your name, address or telephone number will leave the School of Medical Rehabilitation, Pain and Motion Analysis Laboratory.

Voluntary Participation/Withdrawal from the Study

Your decision to take part in this study is voluntary. You may refuse to participate or you may withdraw from the study at any time. Your decision to withdraw will not affect your care in any way at the Health Sciences Centre.

If the study staff feels that it is in your best interest to withdraw you from the study, they will remove you with or without your consent.

We will tell you about any new information that may affect your health, welfare, or willingness to stay in this study.

Medical Care for Injury Related to the Study

You are not waiving any of your legal rights by signing this consent form nor releasing the investigator(s) or the sponsor(s) from their legal and professional responsibilities.

Questions

You are free to ask any questions that you may have about your treatment and your rights as a research participant. If any questions come up during or after the study or if you have a research-related injury, contact the study doctor and the study staff: Dr. Barbara Shay at 787-2756 or Saurabh Mehta at 787-1436.

For questions about your rights as a research participant, you may contact The University of Manitoba, Bannatyne Campus Research Ethics Board Office at (204) 789-3389

Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.

Statement of Consent

I have read this consent form. I have had the opportunity to discuss this research study with Saurabh Mehta and Dr. Barbara Shay or their study staff. I have had my questions answered by them in language I understand. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship (such as employer, supervisor or family member) I may have with the study team has not affected my decision to participate. I understand that I will be given a copy of this consent form after signing it. I understand that my participation in this study is voluntary and that I may choose to withdraw at any time. I freely agree to participate in this research study.

I understand that information regarding my personal identity will be kept confidential, but that confidentiality is not guaranteed. I authorize the inspection of any of my records that relate to this study by The University of Manitoba Research Ethics Board for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

Participant signature_____ **Date** _____

(Day/month/year)

Participant printed name: _____

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has knowingly given their consent

Printed Name: _____ **Date** _____

(Day/month/year)

Signature: _____

Role in the study: _____

Relationship (if any) to study team members: _____

APPENDIX B

Participant Information Form

Name: Study Number:

Age: Gender:

Height:

Body Weight:

Leg Length: Right -- _____ cms. Left – _____ cms.

Knee Width: Right -- _____ cms. Left – _____ cms.

Ankle Width: Right -- _____ cms. Left – _____ cms.

Dates of Data Collection:

First Session (Immediately before the cortisone therapy): Date _____

Second Session (1 week after the cortisone therapy): Date _____

(Day/month/year)

Reference List

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