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UNILATERAL AND BILATERAL KNEE OSTEOARTHRITIS EXHIBIT DIFFERENT KINEMATIC BUT SIMILAR PAIN AND STRENGTH RESPONSES TO AN EXERCISE INTERVENTION

[1] Kathryn Mills, [1]Sean Osis, [1]Blayne Hettinga and [1]Reed Ferber
[1]Running Injury Clinic, Faculty of Kinesiology, University of Calgary, Calgary, Alberta Canada
email: kathryn.agmills@ucalgary.ca

INTRODUCTION

Knee osteoarthritis (OA) is a prevalent and disabling disease defined by disrepair of joint tissue and subsequent breakdown of bone and cartilage [3]. Exercise interventions focusing on strength of the hip and knee musculature are frequently advocated in the management of knee OA to subsequently reduce pain associated with the disease. In intervention studies, individuals with unilateral and bilateral symptoms are often treated in the same group [1]. However, recent cross-sectional evidence that those with unilateral and bilateral OA exhibit different kinematic patterns during walking [5] questions this allocation. What is unknown is whether these cross-sectional differences result in different responses in pain, strength and kinematic outcomes after a conservative rehabilitation program. Therefore, the purpose of the current study was to determine if individuals with unilateral or bilateral symptomatic mild-to-moderate knee OA responded differently to a 6-week muscle strengthening rehabilitation program.

METHODS

Thirty-seven individuals, radiographically and clinically diagnosed with mild-to-moderate knee OA, were recruited (Table 1).

Table 1: Group demographics (mean (SD))

	Unilateral n=19	Bilateral n=18
Age (years)	51.74 (9.05)	55.72 (6.93)
BMI (kg/m^2)	25.55 (3.95)	26.04 (3.27)
Baseline Pain (100 mm)	3.19 (2.11)	4.33 (2.08)
Symptom duration* (years)	2 (1.5-5)	9.5 (6.5-11.25)

*median and IRQ

At baseline, all participants completed a 100 mm visual analogue scale (VAS) indicating their worst pain over the previous week. Bilateral strength of the hip abductors and external rotators and knee flexors and extensors was measured using a force dynamometer (Lafayette Instruments, IN, USA). Positioning for strength testing was standardized and measures were taken by a single tester ($ICC_{(3,k)}$ 0.765 to 0.946). Three-dimensional kinematic data of the lower limbs were collected while participants walked on a treadmill at 1.1 m/s wearing standard laboratory shoes (Pegasus, Nike Air, Oregon, USA). Data were collected at 120 Hz using an 8-camera motion capture system (VICON, Oxford Metrics, Oxford, UK) and 9mm retro-reflective markers as described by Pohl et al [6].

All participants underwent a 6-week graded strengthening program focusing on bilaterally hip abductors, extensors, external rotators and flexors as well as knee extensors. In latter weeks, balance tasks were incorporated. Pain, strength and kinematics measures were repeated at the completion of the intervention period.

Kinematic data were processed in Matlab (version r2010a, Mathworks, MA, USA). Marker trajectories were filtered with a 10Hz low-pass 2nd order recursive Butterworth filter, and 3D rigid body kinematics were calculated using a Joint Coordinate System [4]. Joint angle at initial contact, peak angle during the initial 25% of stance and joint excursion throughout stance phase in the frontal and sagittal planes were determined for the pelvis, hip, knee and ankle bilaterally. These discrete variables were derived from 10 to 20 stance phases.

Changes in pain, muscle strength and kinematics over time were assessed using mixed-model analyses of variance. Group allocation (bilateral or unilateral symptoms) was included as a between-factor and "time" as a within-factor effect in all models. "Years of symptoms" was significantly negatively correlated with the change in pain for individuals in the unilateral group (r=-0.458 p=0.048) and was therefore included as a covariate when examining changes in pain over time. Additional main effects of limb (affected/more symptomatic v. non-affected/less symptomatic) and muscle (hip abductors, external rotators and knee extensors, flexors) were included in the muscle strength ANOVA. Main effects of limb and plane (frontal v. sagittal) were also included in the kinematic model for each joint. Only significant interactions involving group and/or time were of interest to the current study. Significant interactions were followed with univariate tests with Bonferroni corrections.

RESULTS AND DISCUSSION

At the conclusion of the intervention period, 4 participants had withdrawn from the study. One additional participant's kinematic data could not be used. Therefore data for 15 participants in the bilateral group and 17 in the unilateral group were analysed.

There were significant main effects of group ($F=5.41_{(1)}$ p=0.027) and time ($F=19.72_{(1)}$ p=0.00) for pain measures but no interaction. Therefore, while individuals with bilateral knee OA reported an average of 13.6mm (95% confidence intervals: 1.6 to 25.5) more pain than individuals with unilateral symptoms, both group improved by 15.9 mm (9.3 to 22.5) after the strength intervention. This findings is similar to previous studies demonstrating that exercise is efficacious for the pain associated with knee OA [2].

Both groups significantly improved in average muscle strength (2.16 kg (0.8 to 3.52) p=0.003). A significant limb*time interaction revealed the affected/most symptomatic limb exhibited greater improvements in strength than the non-affected/less symptomatic limb. The main effect of muscle was not significant, indicating there were no significant differences in the magnitude of improvement between muscles.

After the interventions, both groups walked with 3.13° (0.88 to 5.38) greater ankle sagittal plane range of motion bilaterally. There were also significant changes in the sagittal and frontal plane knee angles at initial contact. At baseline, there were trends for individuals with bilateral knee OA symptoms contacting the ground with their more symptomatic limb in a position of increased flexion (3.21° (-0.28 to 6.7)) and adduction (2.76° (-0.5 to 6.02)) compared with their less symptomatic limb. After 6-weeks, there were no differences between limbs (0.55° (-2.94 to 4.04) and 1.2°(-2.14 to 4.55). Previous studies have also reported frontal and sagittal plane asymmetry exists in individuals with knee OA [5]. This study, however, is the first to demonstrate that an exercise intervention has the potential to reduce the magnitude of these asymmetries.

Differences between the way individuals with bilateral and unilateral OA symptoms responded to the strength program were evident in frontal plane hip motion and sagittal plane peak pelvis angle during the first 25% of stance phase (Table 2). After the intervention, individuals with bilateral symptoms exhibited increased hip abduction at initial contact, peak angle during the initial 25% of stance and range of motion. In contrast, individuals with unilateral symptoms exhibited increased hip adduction. Similarly, post exercise, individuals with bilateral knee OA exhibited increased posterior pelvic tilt and those with unilateral symptoms walked with reduced posterior tilt. These findings suggest that unilateral and bilateral disease status may influence proximal adaptions to lower limb exercise. However, further research is needed to provide insight into potential clinical implications of these findings, particularly in the light of the lack of between group differences regarding changes in pain over time.

CONCLUSIONS

This study provides further evidence that lower-limb strength-based exercise programs are efficacious in the conservative management of pain associated with knee OA. Strength and kinematic changes were also observed including a reduction in between limb asymmetry in knee sagittal and frontal plane angles at initial contact and a general increase in strength in 4 lower limb muscles. Unilateral or bilateral OA symptoms influenced proximal kinematic responses to the exercise intervention. However, as there was no significant group*time interaction in the pain outcome, it is unlikely that kinematic group differences are associated with differences in symptomatic responses.

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Table 2: Significant between group interactions

Variable	Group	Baseline*	Follow-up*	Mean difference (95% CI)**	Effect size
Hip frontal plane angle at initial contact	Unilateral Bilateral	2.19° (2.93) -1.34° (2.94)	1.34° (2.87) 0.4°(2.88)	-2.59° (-4.69 to -0.49)	0.87
Hip frontal plane angle peak during initial 25% of stance	Unilateral Bilateral	2.72° (2.72) -0.48°(2.71)	1.95° (2.98) 0.75° (2.97)	-2.00° (-4.06 to 0.06)	0.69
Pelvis sagittal plane peak angle during initial 25% of stance	Unilateral Bilateral	0.36° (4.7) 1.98° (4.66)	1.54° (4.85) -0.39 (4.82)	3.55° (0.11 to 6.99)	0.73
Hip frontal plane excursion during stance	Unilateral Bilateral	11.01° (2.51) 9.69° (2.53)	9.16° (3.7) 10.53° (3.72)	-2.69° (-4.98 to -0.4)	0.83

*Estimated marginal means and standard deviations
** Between groups over time