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Improvements in kinematics, muscle activity and pain during functional tasks in females with patellofemoral pain following a single patterned electrical stimulation treatment

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ABSTRACT

Background: Individuals with patellofemoral pain present with altered hip muscle activation, faulty movement patterns, and pain during functional tasks. Examining new treatment options to address these impairments may better treat those with patellofemoral pain. The purpose of this study was to determine if patterned electrical stimulation to the lower extremity affects muscle activity, movement patterns, and pain following a single treatment.
Methods: Fifteen females with patellofemoral pain were randomized to receive a single 15-minute treatment of either a patterned electrical neuromuscular stimulation or a sham. Peak kinematics of the knee, hip, and trunk, electromyography and pain were examined pre and post-intervention during a single leg squat and lateral step-down task. Group means and pre/post reduced kinematic values were also plotted during the entire task with 90% confidence intervals to identify differences in movement strategies.
Findings: No baseline differences were found in peak kinematics between groups. No pre to post-intervention differences in peak knee, hip and trunk kinematics were found, however differences were seen when the quality of movement across the entire tasks was assessed. The electrical stimulation group had improved knee flexion and hip abduction during the lateral step-down. A significant improvement in gluteus medius activation following patterned electrical neuromuscular stimulation occurred during the step-down ($P = 0.039$). Significant pain improvements were also seen in both the single leg squat ($P = 0.025$) and lateral step-down ($P = 0.006$).
Interpretation: A single treatment of patterned electrical neuromuscular stimulation improved muscle activation, lower extremity kinematics during functional tasks, and pain.

1. Introduction

Patellofemoral pain (PFP) is a common lower extremity injury seen in active individuals without the presence of intra-articular damage or true mechanism of injury (Boling et al., 2010). It is a challenging pathology due to the heterogeneous presentation of symptoms between individuals (Piva et al., 2009). It has been documented that those with PFP can have pain with prolonged sitting, stair ambulation, kneeling, squatting, jogging, and pressure to their patella (Aminaka et al., 2011; Nakagawa et al., 2012). This diverse presentation of symptoms suggests why 7.8% of the general population has been diagnosed with PFP and there are even higher rates of treatment for the condition in sports medicine clinics (Boling et al., 2010; Glaviano et al., 2015). It has also been previously reported that 75% of individuals with PFP will decrease or cease their activity due to their pain (Esculier et al., 2013). Furthermore, the recurrence rates for PFP are as high as 90%, leaving some authors to conclude that PFP is an enigma for clinicians (Dye, 2001).

While there are a plethora of reported symptoms between individuals with PFP, females often present with similar trends in their functional limitations, such as hip weakness and altered movement patterns during functional activities (Aminaka et al., 2011; Bolgla et al., 2008; Willson and Davis, 2008; Willson et al., 2012). Females with PFP often present with an increased hip adduction, hip internal rotation, and knee abduction, which have all been theorized to increase patellofemoral joint (PFJ) stress (Aminaka et al., 2011; Nakagawa et al., 2012). This repetitive PFJ stress has been suggested to be a reason why those with PFP have long-term impairments, even after receiving medical treatment (Esculier et al., 2013). In addition to peak kinematic angles, those with PFP have demonstrated altered movement strategies during the entirety of several pain-provoking activities (Willson and Davis, 2008). The quality of movement in those with PFP has not only been identified to be worse than healthy controls, but a linear

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relationship exists between the demands of the task and the magnitude of the discrepancy between PFP and control groups (Willson and Davis, 2008).

The increased hip adduction and internal rotation during functional tasks has led researchers to examine the role of proximal hip musculature, such as the gluteus medius. Females with PFP have been found to present with gluteus medius weakness and have a greater amount of altered neuromuscular control during functional tasks (Boling et al., 2009; Ireland et al., 2003). Clinicians have initiated targeting the hip weakness within clinical practice within this population by focusing rehabilitation exercises targeting the gluteus medius muscle (Khayambashi et al., 2012). While the evidence supports the use of gluteus medius exercises to improve hip strength and decrease pain; there are inconclusive results on strength gains producing improved kinematics (Earl and Hoch, 2011; Willy and Davis, 2013). If strength gains do not affect kinematics in this condition, it suggests that other neuromuscular factors may have a role in individuals with PFP and should be examined. Electromyography (EMG) activity is one such way to examine those neuromuscular factors, and those with PFP have altered activation gluteus medius patterns during functional activities (Barton et al., 2013; Rathleff et al., 2014). Boling et al. (2006) examined EMG activity during functional tasks following a six-week rehabilitation program. While improvements in vastus medalis and vastus lateralis firing patterns occurred from the rehabilitation, there was no change in gluteus medius activation.

Electrical stimulation has been used to improve strength; however utilizing it as a way to address the altered firing patterns has recently gained some attention (Bily et al., 2008; Callaghan and Oldham, 2004; Glaviano and Saliba, in press). Patterned electrical neuromuscular stimulation (PENS) is a precisely timed stimulus delivered in a sequence that was derived from healthy EMG activity on specific muscles to reeducate firing patterns in pathological individuals and improve functional tasks in healthy individuals (Cooke and Brown, 1990). PENS has been found to improve gluteus medius activation and decrease pain following a single intervention in individuals with PFP (Glaviano and Saliba, in press). However, no intervention to date has examined the use of PENS to target the abnormal neuromuscular pattern during functional activity in females with PFP. Therefore, we wanted to evaluate the movement quality by measuring the kinematics in a similar patient population and determine whether a single PENS treatment affected the movement pattern. The purpose of this study was to explore the immediate effects of PENS on movement strategies during a single leg squat and lateral step-down task. Specifically, we aimed to examine the peak knee, hip and trunk kinematics as well as differences in kinematics during the entirety of the two tasks in females with PFP.

2. Methods

This was a double-blinded, randomized, sham controlled laboratory study. Independent variables were treatment group (PENS and Sham) and time (pre- and post-intervention). Dependent variables were lower extremity kinematics, gluteus medius EMG, and visual analog scale during both a single leg squat and lateral step-down task. All dependent variables were collected prior to and post randomized interventions (Table 1).

2.1. Participants

Fifteen females with PFP (age: 26.6 (9.1) yrs, mass: 73.1 (20.1) kg, Height: 172.1 (6.3) cm) were recruited from the local community, sports medicine and orthopedic clinics for participation in this study. Subjects were between the ages of 15–45, had non-traumatic peri- or retro-patella pain greater than 3 months, and pain with more than two of the following activities; stair ambulation, running, kneeling, squatting, prolonged sitting, jumping, contraction of the quadriceps, or pressure to the patella (Cavazzuti et al., 2010; Nakagawa et al., 2013).

Table 1
Anthropometric characteristics of subjects from both groups.

Demographics	PENS ($n = 8$)	Sham ($n = 7$)	P-value
Age, yrs	25.1(7.3)	26.4 (8.7)	0.58
Height, cm	170.9(7.9)	176.7 (7.5)	0.47
Mass, kg	68.6(9.2)	81.5 (22.3)	0.11
AKPS	70.4(11.4)	72.5 (9.2)	0.59
VAS	1.9(1.4)	1.9(0.9)	0.72
Quadriceps RoM, deg	143.3(9.7)	141.2(14.0)	0.74
Hamstring RoM, deg	89.4(6.9)	84.1(13.4)	0.35
Gastrocnemius RoM, deg	11.8(3.6)	8.7(5.7)	0.23
Q-angle, deg	14.6(2.5)	16.0(1.5)	0.24
Tibial torsion, deg	14.3(4.3)	17.2(5.4)	0.28
Navicular drop, mm	1.3(0.5)	0.9(0.4)	0.10
Knee extension strength, nm/kg	5.8(1.0)	4.7(1.9)	0.17
Knee flexion strength, nm/kg	5.7(2.4)	3.9(1.8)	0.12
Hip abduction strength, nm/kg	5.7(2.3)	4.5(2.5)	0.35
Hip adduction strength, nm/kg	5.1(1.3)	3.7(1.7)	0.11
Plantarflexion strength, nm/kg	1.9(1.1)	1.9(1.2)	0.97

The anterior knee pain scale was administered, and the participants were recruited to score <85/100 (Willson and Davis, 2009). Exclusion criteria included: previous knee surgery, ligamentous instability, other source of anterior knee pain (tendonitis, bursitis, patella subluxation, etc.), and previous injury to the back, lower extremity injury or concussion within the last year. A licensed athletic trainer conducted a physical examination, including orthopedic special test for ligamentous instability, palpation to anterior knee anatomical structures and evaluating patella hypermobility, prior to participant enrollment to determine if inclusion/exclusion criteria were met. The participants were also excluded for contraindications to electrical stimulation: implanted biomedical devices, history of neuropathy, hypersensitivity to electrical stimulation, active infection to lower limb or muscular abnormalities. The study received approval from the University's Institutional Review Board and all subjects completed written consent prior to the enrollment.

2.2. Clinical measures

2.2.1. Lower extremity assessment

Lower extremity strength, range of motion and alignment were assessed in all individuals. These assessments were selected due to previously reported influence on lower extremity kinematic, function, and pain in individuals with PFP (Piva et al., 2009). Lower extremity strength was assessed for quadriceps, hamstrings, hip abductors, hip adductors and plantar flexors (Rothermich et al., 2015). These muscles have been previously examined within the PFP population due to the potential distal, local and proximal influence during functional tasks (Aminaka et al., 2011; Bolgla et al., 2008; Nakagawa et al., 2012). Maximal voluntary isometric contraction was assessed with a handheld dynamometer using the "break" method with previously reported testing procedures for each muscle of interest (Marino et al., 1982). Range of motion for the quadriceps, hamstring, and gastrocnemius was calculated with a bubble inclinometer (Piva et al., 2009; White et al., 2009). Lower extremity alignment was assessed for participant's Q-angle, tibial torsion and navicular drop (Piva et al., 2006).

2.2.2. Kinematics

Kinematic data was captured through the Flock of Birds electromagnetic tracking system (Ascension Technology, Inc., Burlington, VT, USA) using Motion Monitor Software (Innovative Sports Training, Inc., Chicago, IL, USA). The subject was set up for motion capture system: using eight sensors, one on dorsal aspect of each foot, one on the middle third of each lateral shank, one on the middle third of each lateral thigh, one over the sacrum, and one at T1; then height, weight, and joint centers were then calibrated using the stylus. Data was collected at a sampling rate of 144 Hz.