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Effects of neuromuscular reeducation on hip mechanics and functional performance in patients after total hip arthroplasty: A case series

Dana L. Judd *[,1], Joshua D. Winters [1,2], Jennifer E. Stevens-Lapsley [3], Cory L. Christiansen [3]

University of Colorado Anschutz Medical Campus, Physical Therapy Program, 13121 E. 17th Ave, Mail Stop C244, Aurora, CO 80045, USA

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ABSTRACT

Background: Following total hip arthroplasty, patients demonstrate compensatory movement strategies during activities of daily living such as walking and stair climbing. Movement compensations are important markers of functional decline in older adults and are related to poor functional capacity. Despite increased utilization of hip arthroplasty, persistent movement compensation, and functional performance deficits, no consensus on postoperative rehabilitation exists. Neuromuscular reeducation techniques offer a strategy to improve movement quality by emphasizing hip abductor performance and pelvic stability. This case series illustrates changes in movement strategy around the hip in response to targeted neuromuscular reeducation techniques after hip arthroplasty.

Methods: Five participants received an 8-week exercise program following total hip arthroplasty, emphasizing targeted neuromuscular reeducation techniques hallmarked by specific, weight-bearing exercise to improve hip abductor performance and pelvic stability. Five additional participants were supervised and followed for comparison.

Findings: Participants in the neuromuscular reeducation program improved their internal hip abductor moments and vertical ground reaction forces during walking and stair climbing. They also improved their functional performance and hip abductor strength outcomes.

Interpretation: Targeted neuromuscular reeducation techniques after total hip arthroplasty provided a positive effect on biomechanical outcomes, functional performance, and muscle strength. Through focused use of the hip abductor muscles, increased internal hip abductor moments were observed. This intervention potentially promotes pelvic stability, and may contribute to improved performance on tasks such as stair climbing, fast walking, and balance. The results suggest that neuromuscular reeducation offers a unique effect on movement strategy and function for patients following total hip arthroplasty.

1. Introduction

Total hip arthroplasty (THA) has become one of the most common orthopedic surgeries (Di Monaco and Castiglioni, 2013). In the next 15 years, the THA surgery rate in the United States is expected to increase by 174%, to more than 500,000 per year (Kurtz et al., 2007; Nho et al., 2013). Despite the increase in utilization of THA, there is no consensus for rehabilitation exercise guidelines after THA (Vissers et al., 2011). Exercise following THA can safely improve physical function and strength outcomes following THA (Di Monaco and Castiglioni, 2013; Husby et al., 2009, 2010; Minns Lowe et al., 2009; Rahmann et al., 2009; Wang et al., 2002). However, variable approaches to timing of initiation, mode, and dose of exercise have led to a lack of agreement on optimal exercise prescription following THA (Di Monaco and Castiglioni, 2013). Moreover, existing exercise studies have not focused on the persistent movement compensations observed after THA.

Compensatory movement strategies, such as asymmetrical limb loading (Talis et al., 2008), asymmetrical power production and muscle activation (Lamontagne et al., 2011), and ipsilateral lumbar side bending combined with decreased hip abduction moment (Perron et al., 2000), have been observed in patients after unilateral THA during daily activity (Talis et al., 2008), walking (Perron et al., 2000; Sicard-Rosenbaum et al., 2002), and stair climbing (Lamontagne et al., 2011). These movement compensations may relate to poor physical function after THA. In particular, abnormal muscle control at the hip and pelvis during gait, which often results in an abnormal gait pattern, is indicative of low internal hip abduction moments which are related to slow walking speeds observed after THA (Foucher et al., 2007; Foucher et al., 2011; Kolk et al., 2014; Perron et al., 2000). Some

* Corresponding author at: 13121 E. 17th Ave, Mail Stop C244, Aurora, CO 80045, USA.
E-mail address: Dana.Judd@ucdenver.edu (D.L. Judd).
[1] Drs Judd and Winters would like to be acknowledged as first co- authors.
[2] Present address: University of Kentucky, College of Health Science, 900 South Lime Street, Lexington, KY 40536, USA.
[3] Veterans Affairs Geriatric Research, Education and Clinical Center, Denver, CO.

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investigations suggest that walking mechanics never return to normal following THA (Beaulieu et al., 2010). Movement compensations have been found to serve as important biomarkers of functional decline in a variety of older adult populations (Clough-Gorr et al., 2008; Higgins et al., 2014) and are linked to increased fall risk (Clough-Gorr et al., 2008; Higgins et al., 2014) and poor functional outcomes (Christiansen et al., 2011), thus highlighting the importance of addressing these compensations through postoperative exercise programs.

The resolution of persistent movement compensations requires targeted exercise to improve the ability of the body to produce stable, coordinated movements during functional tasks. Such exercise is clinically referred to as neuromuscular reeducation (NMR) (Ageberg et al., 2010). At the hip and pelvis, stability is largely dependent on the hip abductor muscles' ability to produce internal hip abduction moments to control pelvic motion during unilateral stance (Grimaldi, 2011; Hardcastle and Nade, 1985). Optimal NMR targets movement compensations by promoting coordinated hip and pelvic muscle activity and pelvic stability (Willson et al., 2005), which requires integrating strength training with focused movement reeducation feedback techniques, rather than isolated strength training (Willy and Davis, 2013). Hip abductor muscles actively respond to movement perturbations during function to maintain a stable pelvic base (Willson et al., 2005). Without such pelvic stability, movement compensations occur, such as a Trendelenburg gait pattern, which may negatively impact walking performance and create difficulty performing activities of daily living that may lead to further injury (Akuthota et al., 2008).

NMR techniques can be used to target the hip abductor muscles' ability to stabilize the pelvis by resisting external moments during functional tasks. NMR techniques have successfully improved strength and postural stability (McKeon et al., 2008; O'Driscoll and Delahunt, 2011), gait kinematics (McKeon et al., 2009), and movement patterns, while also reducing the risk of injury in other populations such as patients with ankle injury and anterior cruciate ligament reconstruction (Hewett et al., 2006; McKeon and Hertel, 2008). However, the efficacy of targeted NMR techniques to improve hip abductor performance, movement quality, and functional performance after THA is unknown.

The purpose of this case series was to describe the changes in movement strategy during daily tasks resulting from the use of targeted NMR techniques during postoperative THA rehabilitation. We hypothesized that NMR techniques would 1) increase the involved limb internal hip abductor moments and vertical ground reaction forces during walking and stepping compared with a typical course of care after THA and 2) improve functional performance and isometric hip abductor strength.

2. Methods

2.1. Participants

Ten participants were recruited from one of two area hospitals by physician referral or advertisement at preoperative educational sessions. Inclusion criteria included primary posterior approach THA for the treatment of hip osteoarthritis, aged 50–75 years. Exclusion criteria included a history of uncontrolled diabetes, body mass index >40 kg/m^2, or additional orthopedic or neurologic pathology that impaired function. Five participants completed a neuromuscular reeducation exercise intervention (NMR). Additionally, five participants were supervised and followed for comparison (CON). Patients were assessed preoperatively and postoperatively, following the completion of the intervention. Testing and NMR group rehabilitation occurred within the Muscle Performance Laboratory at the University of Colorado, Anschutz Medical Campus. All participants were provided written, informed consent and this study was approved by the Colorado Multiple Institutional Review Board.

2.2. Intervention

The NMR group participated in outpatient rehabilitation 2×/week (approximately 45 min per session) for 8 weeks. The CON group was supervised by the study physical therapist, and advised on continuing exercise programs initiated in the hospital, but did not attend outpatient rehabilitation, which represents current practice patterns in the community.

2.2.1. Neuromuscular reeducation exercise program

The NMR program combined strength training with focused techniques emphasizing use of the hip abductors to stabilize the pelvis, thus improving movement quality to maximize functional recovery. These techniques included specific, weight-bearing exercise aimed to improve hip abductor performance and pelvic stability. Specifically, participants progressed through bilateral, then unilateral weight-bearing tasks, which included both static and dynamic functional tasks. These activities were supervised closely by the therapist who provided verbal, visual, and tactile cues to promote pelvic stability. These techniques were also used to promote the use of the hip abductors as a means to maintain a horizontal pelvic alignment during performance of the tasks. Progression of these activities was based on the ability of the participant to achieve the desired posture and movement quality. Specifically, the participants had a band around their pelvis at the level of the anterior, superior iliac spines of the pelvis, placed by the therapist, and used a mirror to visualize ability to maintain the band, and thus the pelvis, horizontal during the task. These tasks were further progressed to more unstable surfaces, such as foam and BOSU ball, to increase task difficulty. This exercise protocol also included core stabilization exercise focusing on lower abdominal muscle training to enhance pelvic stability, and functional mobility training. Functional training progressed from basic gait training with an assistive device to agility training which included stair climbing, side stepping and carioca stepping with increasing speed. Visual, verbal, and tactile cues were provided for participants to attempt to maintain a stable, horizontal pelvis during gait and agility training activities. Finally, the NMR program included progressive, resistance strength training to remediate strength in the major hip and thigh musculature impacted by THA (Judd et al., 2014a). The exercises included use of weighted pulleys and weight-training machines. Therapists determined an 8-repetition maximum for each muscle group and weight was increased by at least 10% every 2 weeks to maximize muscle hypertrophy and strength gains. The NMR program included both supervised clinic-based exercise and home exercise to maximize movement quality, muscle strength and functional performance.

2.2.2. Control group program

Participants in the CON group received weekly 30–45-minute home visits by study staff during the first 6 weeks of the intervention period and then were contacted by phone for the last 2 weeks. Participants received continued education on the exercises received during their hospital stay, such as activities to improve range of motion, flexibility and isometric muscle training, which patients typically continue independently after hospital discharge. They also received education regarding functional training and safety for activities of daily living. As there is no widely accepted standard of care for rehabilitation following THA (Di Monaco and Castiglioni, 2013) and discussions with local physical therapists within our partner hospitals indicated that patients do not routinely receive outpatient rehabilitation services, this control group closely mirrored usual postoperative care typically received in the community.

2.3. Outcomes

All outcomes were assessed preoperatively and at the completion of the intervention period. One investigator (JW) performed the