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Influence of weight bearing visual feedback on movement symmetry during sit to stand task

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A B S T R A C T

Background: Weight-bearing asymmetry is common in individuals with hip osteoarthritis and after total hip arthroplasty. Including symmetry training to the rehabilitation programs may normalize movement strategies during dynamic tasks. The purpose of this study was to evaluate the immediate influences of real-time visual feedback of weight distribution on the interlimb movement symmetry during the sit-to-stand task, before and after total hip arthroplasty, and to determine whether physical impairments affect the response to visual feedback.

Methods: Subjects before and after total hip arthroplasty participated in three- dimensional motion analysis. Subjects completed 3 trials of sit-to-stand task in two conditions; "without visual feedback" and "with visual feedback". Outcome measures were the interlimb symmetry of vertical ground reaction force, and joint kinematics and kinetics. Pain and strength of lower limbs were assessed.

Findings: Compared to "without visual feedback" condition, subjects moved with greater symmetry of vertical ground reaction force and joint kinetics when visual feedback was received. However, subjects continued to demonstrate interlimb difference for joint kinetics and vertical ground reaction force in the visual feedback condition. The increase in symmetry was not strongly influenced by physical impairments and subjects before and after total hip arthroplasty responded similarly to the feedback.

Interpretations: We concluded that in a single session, the visual feedback of weight bearing distribution had a positive immediate effect on movement symmetry during the sit-to-stand task. Future studies that assess long-term retention and functional benefits are warranted before visual feedback is incorporated in rehabilitation for this patient population.

1. Introduction

Asymmetrical weight bearing is common in individuals with unilateral hip osteoarthritis (OA), before and after total hip arthroplasty (THA). Before and after THA, individuals use compensatory strategies to complete common activities of daily living, such as the sit-to-stand task (STS) (Abujaber et al., 2015a; Boonstra et al., 2011; Eitzen et al., 2014; Martinez-Ramirez et al., 2014; Talis et al., 2007; Talis et al., 2008). During the STS, these individuals rely on the non-affected limb to complete the activity, which results in 17–22% less vertical ground reaction force under the affected limb (Boonstra et al., 2011; Talis et al., 2008) and asymmetrical hip and knee joint moments that are lower on the affected side (Eitzen et al., 2014; Lamontagne et al., 2012; Varin, 2011).

Altered movement patterns that persistently underload the affected side and overload the contralateral side, may have negative short- and long-term consequences. Christiansen and colleagues found that greater weight bearing asymmetry during STS task was related to worse functional performance in patients after knee arthroplasty (Christiansen et al., 2011). Reducing the joint moments and forces on the surgical side may perpetuate a pattern of disuse atrophy. In addition, the pattern of overloading the non-surgical limb coincides with the non-random progression of OA in lower extremity joints. Shakoor et al. found that the contralateral hip joint and the contralateral knee joint were the next most likely joints to show OA progression and require replacement after an initial THA (Shakoor et al., 2002).

Because most patients experience substantial pain relief after THA, the persistent unloading strategy after THA may be a learned behavior

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that develops due to joint pain or weakness prior to THA. It is also possible that post-operative factors, such as joint instability, decreased proprioception or fear of movement perpetuate the movement asymmetries and learned behavior after THA (Boonstra et al., 2011; Talis et al., 2007). Therefore, addressing this movement impairment through targeted strategies such as movement feedback is warranted. In recent studies, real time visual feedback of weight distribution has been found to reduce weight bearing asymmetry in healthy adults during a squat task (McGough et al., 2012), and in patients with neurological diseases during static standing (Foo et al., 2013). Visual feedback of weight distribution has also improved movement symmetry and function for patients after joint arthroplasty (McClelland et al., 2012; Zeni et al., 2013).

Despite the potential benefit of this visual feedback of weight distribution, the joint-specific strategies used to normalize weight distribution during the chair rise have not been examined. If patients improve symmetry in ground reaction force, it is important that this change does not come as a consequence of kinetic or kinematic compensations at other joints. It is possible that joint moments and angles, or the trunk angle, will become more asymmetrical in an attempt to make force under each limb more symmetrical.

It is imperative to discern how subjects who exhibit weight bearing asymmetry implement movement strategies that normalize ground reaction force between limbs when receiving visual feedback. Therefore, the purpose of this study was to evaluate the immediate influence of real-time visual feedback of weight distribution under limbs, on lower extremity kinematics and kinetics during a STS task in subjects before and after THA. We hypothesized that 1) subjects before and after THA would demonstrate increased symmetry in weight bearing, as well as in joint kinematics and kinetics, when receiving visual feedback; 2) strength and pain of the operated limb will influence the magnitude of change in symmetry when receiving feedback; 3) subjects after THA will demonstrate larger increase in symmetry in response to the visual feedback compared to those in subjects before THA. Specifically we hypothesized that greater pain and less strength would attenuate the effect of visual feedback so that subjects after THA would have a greater response.

2. Methods

2.1. Subjects

Subjects in this study were derived from a parent longitudinal study that evaluated the functional performance and movement patterns in patients before and after THA. Participant in parent study were subjects with end-stage hip OA between the ages of 35 and 85, who were scheduled to undergo THA between March 2012 and October 2014. Subjects were either referred by local orthopedic surgeons or responded to newspaper advertisements. Before enrollment, subjects were screened for eligibility using a telephone interview conducted by our research staff. Subjects were excluded if they had 1) neurological disorders that affect their ability to walk or rise from a chair, 2) any cardiovascular problems that limiting them their ability to climb a flight of stairs or walk for 6 min, 3) uncontrolled hypertension, or 4) history of cancer in the lower extremity. To avoid the potential confounding influence of other joint impairments, subjects were also excluded from this analysis if they 1) had previous arthroplasty surgery within 1 year of the pre-operative evaluation; or 2) planned to have an additional lower extremity arthroplasty. All surgical procedures were performed by anterolateral, posterior or direct lateral approach (Table 1).Three-dimensional motion analysis, and functional evaluation sessions were completed at 2–4 weeks prior to THA and 3 months after THA. However, the subjects included in this study did not necessarily complete the visual feedback testing at both time points primarily due to the fact that the visual feedback was added after the parent study started enrolling. In addition, not all subjects returned for follow-up testing and time constraints may have prevented some subjects from completing the visual feedback portion at one of the time points. The resulting sample consisted of most patients who completed this testing at only one time point. Because we have two different groups before and after THA, we performed our analysis in a cross-sectional fashion using analytical techniques consistent with that study design. The study was approved by the Human Subjects Review Board at the University of Delaware and all subjects provided informed consent prior to participation.

Table 1
Subject's characteristics and clinical measures before and after THA.

Variable	Mean(SD) Before THA (N = 35)	Mean(SD) After THA (N = 27)
Age (years)	63.6 (8.0)	62.4 (8.1)
Height (m)	1.73 (0.10)	1.74 (0.10)
Mass (Kg)	88.8 (20.5)	90.74 (22.2)
BMI (kg/m^2)	29.3 (5.3)	29.9 (5.8)
Sex. Male/female (n)	23/12	15/12
Affected side. Right/left (n)	17/18	13/14
Op. Hip pain (1–10)	5.8 (2.3)	1.3 (1.5)
Nop. Hip pain (1–10)	0.4 (1.0)	0.3 (0.8)
Op. Hip abductor strength (N/Kg)	1.51 (0.80)	1.49 (0.84)
Nop. Hip abductor strength (N/Kg)	2.08 (0.85)	2.08 (0.89)
Op. Knee extensor strength (Nm/Kg)	1.27 (0.64)	1.48 (0.61)
Nop. Knee extensor strength (Nm/Kg)	1.75 (0.74)	1.76 (0.69)
Surgical approach. posterior/ anterolateral/direct lateral	–	19/7/1

BMI: body mass index. Op: operated side. Nop: non-operated side.

2.2. Anthropometric measures

Age, height, weight and sex were recorded, and body mass index (BMI) was calculated for each subject.

2.3. Motion analysis

The STS task was analyzed by using a three dimensional 8-camera motion capture system (VICON, Oxford Metrics, London, England) synchronized with two embedded force platforms (Bertec Corp., Worthington, OH, USA). Sixteen-millimeter spherical retro-reflective markers were placed bilaterally on anatomical structures that were used to define joint segments during the static trial. Markers were placed on the iliac crest, greater trochanter, lateral femoral condyle, lateral malleolus, head of the 5th metatarsal, and 2 markers on the heel. Knee and ankle joint centers during a static trial were computed by using medial markers that were placed bilaterally on medial femoral condyle, medial malleolus, and on head of the 1st metatarsal bone. To track segmental motion during dynamic trials, rigid thermoplastic shells with 4 markers were secured to the trunk at mid-thoracic area lateral to the spine and bilaterally on the lower legs and thighs. Pelvic motion was tracked using a shell with 3 markers placed below the line between the 2 posterior superior iliac spines. Functional hip joint centers were determined using a built-in algorithm that calculates the most likely intersection of all axes (effective joint center) and most likely orientation of the axes (effective joint axis) between the pelvis and femur based on a separate dynamic trial in which subjects performed hip flexion, extension and abduction during single leg stance (Schwartz and Rozumalski, 2005). "Start stand" and "end stand" events were determined using the velocity and position of the acromio-clavicular (i.e. shoulder) marker, respectively.

Marker data and force platforms data were sampled at 120 Hz and 1080 Hz, and were filtered at 6 Hz and 40 Hz, respectively. Visual 3D (C-Motion, Inc., Germantown, MD, v5.00.25) software program was utilized to compute joint angles and joint moments for each limb by