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The effect of total hip and hip resurfacing arthroplasty on vertical ground reaction force and impulse symmetry during a sit-to-stand task

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ABSTRACT

Background: The aim of this study was to determine the influence of total hip arthroplasty and hip resurfacing arthroplasty on limb loading symmetry before, and after, hip reconstruction surgery during a sit-to-stand task.

Methods: Fourteen patients were recruited that were about to receive either a total hip prosthesis ($n = 7$) or a hip resurfacing prosthesis ($n = 7$), as well as matched controls. Patients performed a sit-to-stand movement before, 3 months after, and 12 months after surgery. Peak vertical ground reaction force and impulse were measured for each leg, from which ground reaction force and impulse symmetry ratios were calculated.

Findings: Before surgery, hip resurfacing patients showed a small asymmetry which was not different to normal for ground reaction force (0.88(0.28) vs. 1.00(0.11); $p = 0.311$) or impulse (0.87(0.29) vs. 0.99(0.09); $p = 0.324$) symmetry ratios. Total hip patients offloaded their affected hip by 30% in terms of impulse symmetry ratio (0.71(0.36) vs. 0.99(0.23); $p = 0.018$). At 3 months following surgery asymmetries were seen that were different to normal in both hip resurfacing patients for ground reaction force (0.77(0.16); $p = 0.007$), and total hip patients for ground reaction force (0.70(0.15); $p = 0.018$) and impulse (0.72(0.16); $p = 0.011$) symmetry ratios. By 12 months after surgery total hip patients regained a symmetrical loading pattern for both ground reaction force (0.95(0.06); $p = 0.676$) and impulse (1.00(0.06); $p = 0.702$) symmetry ratios. Hip resurfacing patients, however, performed the task by overloading their operated hip, with impulse symmetry ratio being larger than normal (1.16(0.16); $p = 0.035$).

Interpretation: Physiotherapists should appreciate the need for early recovery of limb loading symmetry as well as subsequent differences in the responses observed with different prostheses.

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1. Introduction

Hip reconstruction surgery is the primary intervention for the treatment of hip osteoarthritis and is generally a highly successful procedure (Learmonth et al., 2007). Over the past few decades, people presenting with hip osteoarthritis have become younger (Crowninshield et al., 2006). Hip resurfacing arthroplasty (HRA) is currently the preferred option for younger osteoarthritic patients as it better restores the original hip anatomy (Girard et al., 2006), helping patients to return to more active lifestyles (Lavigne et al., 2011), and preserves bone stock which potentially allows easier revision surgery when required (Mont et al., 2007).

Total hip arthroplasty (THA) is known to be limited in its ability to restore normal hip joint biomechanics (Ewen et al., 2012). Previously, HRA has been shown to lead to better recovery of hip joint biomechanics compared to THA (Girard et al., 2006). Nantel et al. (2009) reported more normal sagittal plane biomechanics during gait in resurfacing patients compared to THA patients. Mont et al. (2007) reported increased walking speed in hip resurfacing patients, as well as increased hip extension and abduction moments during gait. Shrader et al. (2009) reported a more symmetrical gait in hip resurfacing patients.

Rising from a chair is a task performed many times each day in healthy people (Dall & Kerr, 2010). In patients with hip osteoarthritis, their ability to perform this task becomes impaired, and an offloading of the affected limb has been reported, even after THA (Boonstra et al., 2011; Talis et al., 2008). To date, however, no studies have compared the symmetry of limb loading during a sit-to-stand task between total hip and HRA patients; neither have any studies reported limb loading asymmetries in pre-surgical hip osteoarthritis patients. The aim of this study, therefore, was to determine the limb loading symmetry during a sit-to-stand movement in these patient populations, both before and after surgery. It was hypothesised that hip resurfacing patients would demonstrate a more symmetrical loading pattern than THA patients following surgical reconstruction of their hip, potentially due to better restored hip extensor and abductor moments.

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2. Methods

2.1. Participants

Fourteen patients undergoing either primary THA or HRA, as a result of osteoarthritis of the hip, took part in this study. The THA group included seven male patients with a mean (SD) age, height and mass of 63.8 (7.6) years, 1.73 (0.09) m, and 89.3 (12.5) kg, respectively. Patients in this group received a 36 mm total hip prosthesis using the Hardinge or modified Hardinge anterolateral approach. Patients in the HRA group included six male patients and one female patient, and had a mean (SD) age, height and mass of 54.6 (12.0) years, 1.72 (0.08) m, and 84.7 (9.15) kg, respectively. These patients received a hip resurfacing prosthesis using the Hardinge or modified Hardinge anterolateral approach.

Patients were excluded if they had previously undergone surgery to either leg, had inflammatory arthritis of the hip, infection of the hip joint, a body mass index of greater than 35, severe vascular insufficiency on the affected limb, marked bone loss around the hip, or were unable to walk without assistance. Patients were also excluded if they were receiving a bilateral hip replacement where the second joint replacement procedure was planned within the 12 months after the first operation to ensure that data collected as part of this study was not influenced by a second operation.

Two groups of healthy control participants were also recruited to determine how well limb loading symmetry was restored towards normal in each patient group. Each control group was age, height, mass and gender matched to their respective patient group. Table 1 presents demographic information for each patient group along with their respective control group. The study was approved by the local National Health Service ethics review board, the local hospital trust Research and Development committee, and the institutional review board of the host academic institution. All patients and healthy controls gave fully informed written consent to take part in the study.

2.2. Equipment

Kinematic data were collected using a Vicon MX optical motion tracking system (Vicon Motion Systems, Oxford, UK) with 12T20 near-infrared cameras. These were connected to two Vicon MX Giganet core processor units which were in turn connected to a Dell Precision T7500 workstation (Dell UK, Bracknell, UK) running Vicon Nexus version 1.7 software. The T20 cameras had a resolution of 2 megapixels and were set to collect data at a frame rate of 200 Hz.

Kinetic data were collected using two floor mounted force platforms (OR6-7, AMTI, Watertown, MA) positioned directly adjacent to each other (Fig. 1). Each force platform was connected to a digital strain gauge amplifier (MSA-6, AMTI, Watertown, MA.) with the gain on each channel set to 4000. The amplified signals were subsequently connected to one of the MX Giganet units which sampled them at 1000 Hz. The force platforms had a stated linearity of 0.2% and a stated hysteresis of 0.2%.

Table 1
Patient and control group demographic information.

	HRA		THA	
	Patients	Controls	Patients	Controls
Age (years)	54.6 (12.0)	53.3 (10.8)	63.8 (7.6)	64.5 (8.1)
Mass (kg)	84.7 (9.2)	77.0 (7.9)	89.3 (12.5)	77.1 (11.8)
Height (m)	1.72 (0.08)	1.75 (0.07)	1.73 (0.09)	1.73 (0.06)
Male/female	5/2	5/2	7/0	7/0

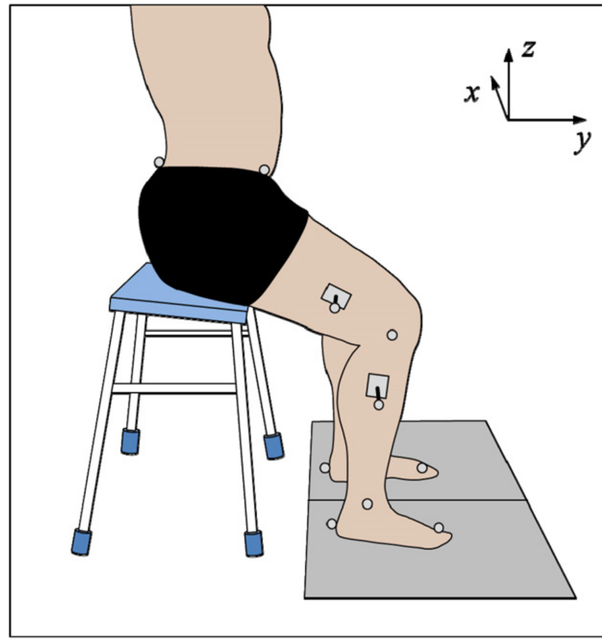

Fig. 1. Illustration of the experimental setup, showing the starting position of each participant, the location of the two force platforms, and the markers used for the determination of lower limb kinematics.

2.3. Protocol

Patients attended the gait laboratory on three occasions. The first visit was in the week prior to surgery, the second visit was 3 months following surgery and the third visit was 12 months following surgery. Twelve months was selected as the final follow-up to ensure that the majority of rehabilitation had taken place. Healthy control participants attended on a single occasion. On each visit, patients and control participants performed the same task. Twelve 14 mm retroreflective markers were attached bilaterally to the anterior superior iliac spine, posterior superior iliac spine, lateral femoral epicondyle, lateral malleolus, posterior aspect of the calcaneus, and second metatarsal head according to the Vicon Plug-in Gait marker set (Vicon Motion Systems Limited, 2010). Additional markers, located on the ends of 70 mm wands, were placed on the lateral aspect of the thigh and lower leg (Fig. 1). All markers were attached to the skin using double sided adhesive tape. To assist in the accurate placement of markers, patients and control participants wore shorts and were asked to remove their shoes and socks. All trials were performed barefoot.

An initial static upright standing trial was obtained. Patients were then asked to sit on a stool (Nottingham Rehab Supplies, Ashby de la Zouch, UK) positioned next to the two force platforms, such that one foot was positioned on each platform (Fig. 1), with arms placed across their chest. The feet were positioned level with each other such that the lower legs were vertical. An instruction was then given to stand up from the stool, without using their hands, until a standing position was achieved. This movement was repeated three times by each patient and control participant during each visit to the laboratory.

2.4. Data processing

Each of the three trials for each patient and control participant was reconstructed and markers labelled. The start of the sit-to-stand task was defined as the instant when vertical ground reaction force (vGRF) reached its minimum value in the counter movement phase (Abe et al., 2010). The end point of the sit-to-stand task was taken to be

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