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Lecture

Asymmetrical loading during sit-to-stand movement in patients 1 year after total hip arthroplasty

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ABSTRACT

Background: Asymmetrical loading during functional performance can occur after total hip arthroplasty. We hypothesized that during sit-to-stand movements, the loading of the limbs of patients who undergo total hip arthroplasty is more asymmetrical than that of those who do not. The objective of the present study was to compare asymmetrical loading during the sit-to-stand movements of patients at 1 year after undergoing total hip arthroplasty, and that of healthy adults.

Methods: Twenty-eight patients at 1 year after undergoing total hip arthroplasty and 16 healthy adults were included. We measured the vertical ground reaction force during the sit-to-stand movement for each leg and calculated the ratio of the peak vertical ground reaction force, and the ratio at the time of peak magnitude of the non-operated limb (control, right limb).

Findings: The mean peak vertical ground reaction force ratio of the patients was 0.77 (0.2), and it was significantly lower than that of healthy adults. The vertical ground reaction force ratio for these patients at the time of peak magnitude of the non-operated limb was 0.72 (0.2), and was significantly lower than that of healthy adults.

Interpretation: Loading on the operated leg during the sit-to-stand movement was lower than that on the non-operated leg in patients at 1 year after undergoing total hip arthroplasty. Furthermore, loading during sit-to-stand movement of patients 1 year after undergoing total hip arthroplasty was more asymmetrical than that of healthy adults. Even at 1 year after undergoing total hip arthroplasty, these patients performed the sit-to-stand movement asymmetrically.

1. Introduction

Total hip arthroplasty (THA) relieves pain and improves physical functioning in patients with advanced osteoarthritis (OA) of the hip. (Nilsdotter and Isaksson, 2010; Rat et al., 2010) However, offloading from the operated leg can occur during the functional performance of patients who undergo THA.(Boonstra et al., 2011; Caplan et al., 2014; Talis et al., 2008) Asymmetrical loading during functional performance could affect the recovery of the operated leg's muscle strength and the load on the contralateral lower joints. It is therefore important to assess asymmetrical loading. Overloading of the contralateral knee joint for a long time could be a risk factor for the progression of knee OA,(Shakoor et al., 2002; Suter et al., 1998) and the rate of the occurrence of knee OA in the non-operated leg of patients who undergo THA is higher than that in those who do not undergo THA.(Umeda et al., 2009)

Boonstra et al.(Boonstra et al., 2011) and Talis et al.(Talis et al., 2008) indicated that asymmetrical leg loading was remarkable in patients who performed the sit-to-stand movement (STS) compared to those who performed quiet standing and walking, and asymmetry remained, even about 1 year after the patients underwent THA. After a rehabilitation period longer than 12 months, patients who received THA still performed the STS asymmetrically by offloading weight from their operated limb. Asymmetrical loading of the lower limbs during the STS is clinically important,as the STS is performed, on average, more than 60 times per day.(Dall and Kerr, 2010) In order to lift the weight of the body against gravity, the patient must produce an upward velocity, which is a good general indicator of function and performance.(Dall and Kerr, 2010; Earles et al., 2001; Egerton and Brauer, 2009; Nuzik et al., 1986; Su et al., 1998) Therefore, comparison of the instantaneous peak vertical ground reaction force (vGRF) for the

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operated and non-operated lower limb could provide a useful index of the asymmetry of lower limb loading during STS after THA.(Caplan et al., 2014) Our underlying hypothesis states that, compared to the control group, asymmetry in lower limb loading during STS would persist in patients with a THA, 1 year post-surgery. Specifically, our aim in this study was to measure the difference in the timing of the peak vGRF for the operated and non-operated lower limb during STS and the difference in the symmetry of the instantaneous vGRF between patients who have undergone THA compared to a control group of adults without lower limb impairment.

2. Methods

2.1. Participants

In 2013, 160 patients with end-stage OA of the hip underwent THA at our institution. Of these, we only selected women for our study to control for sex-specific differences in the performance of STS. As well, we excluded patient who had undergone revision or bilateral THA, those with OA in the non-operated hip joint and those who had a leg length discrepancy greater than 5 mm. Twenty-eight patients who underwent unilateral, primary THA (THA group) participated in the present study (Fig. 1). A single surgeon performed all operations with a posterolateral approach. All patients remained in the clinic for 28 days postoperatively and received physical therapy 6 days per week. Physical therapy started 1 day postoperatively, and composed of range of motion exercises, muscle strengthening, gait, aerobic exercise, postural restoration exercise and activity of daily living (ADL) training. The patients were permitted partial weight bearing with double crutches 2 days postoperatively and full weight bearing with a cane at 2 weeks. They were instructed to continue their tailored exercises at home. In outpatient rehabilitation, patients were assessed regarding their performance of physical function and ADLs and provided with a tailored home program of exercise to address identified limitations. All patients were able to walk with a cane for more than 20 min at 4 weeks postoperatively and were able to walk without a cane at 1 year postoperatively. Sixteen age-matched women, without a history of lower limb pain or sensory-motor impairment, were recruited through friends and relatives of the patients and colleagues at our institution. The study was approved by our institution's ethics review board. We adhered to the principles outlined in the Declaration of Helsinki, and all participants were informed of the procedures before they consented to participate, and signed an informed consent statement.

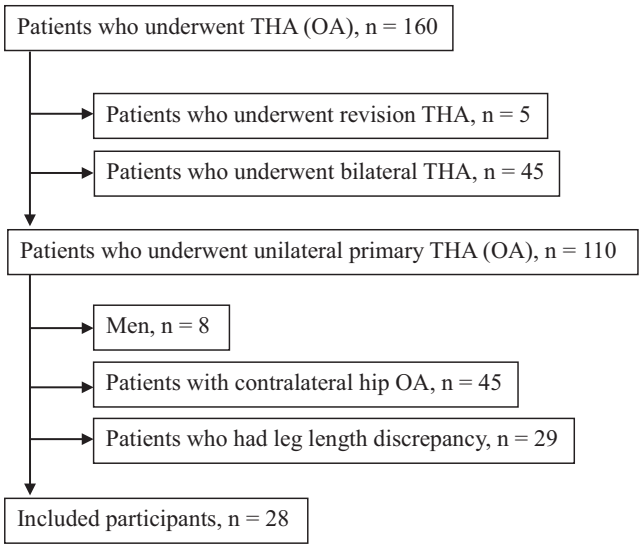

Fig. 1. Flowchart describing recruitment and reasons for nonparticipation THA: total hip arthroplasty; OA: osteoarthritis.

Fig. 2. The experimental setup, showing the location of the platform, an armless chair, and the display.

2.2. Procedures

The Pressure Distribution Measurement Platform with Win PDMS software (Zebris Medical GmbH, Isnyim Allgäu, Germany) was used to simultaneously measure the vGRF (N) under the left and right foot during the STS. This platform has 1506 pressure sensors that are placed at 1-cm intervals on a 320 × 470-mm grid. The range of measurable pressure is 1–120 N/cm^2. The sampling frequency is 50 Hz. A platform and armless chair were set up (Fig. 2). The participants were blinded to the display, which showed the percentage values and color scale of the force distribution. The patients were measured 1 year after undergoing THA. The participants were asked to sit on an armless chair (seat height: 45 cm).(Weiner et al., 1993) They sat comfortably on the chair, with bare feet placed on the platform, and were asked to stand up from the chair at their usual speed, keeping their arms hanging freely by their side (i.e., no contribution by the upper limbs). The endpoint of the STS task was when the participant was able to stand upright. We did not attempt to control their posture further.(Janssen et al., 2002) During the STS, the vGRFs of the left and right feet were measured. Before recording the STS performance, participants were provided with two practice trials. All participants could perform the STS independently without assistive devices. We used the following Symmetry Index (SI) and Symmetry Index (t) (SIt):

$$\mathrm{SI} = \frac{\text{peak vGRF of the operated leg [F1]}}{\text{peak vGRF of the non}-\text{operated leg [F2]}}$$

$$\mathrm{SIt} = \frac{\text{vGRF of the operated leg at } t \text{ [F3]}}{\text{peak vGRF of the non}-\text{operated leg [F2]}}$$

where t is the time point when the vGRF of the non-operated leg reached the peak (Fig. 3).

For the control group, we used the following SI and SIt:

$$\mathrm{SI} = \frac{\text{peak vGRF of the left leg [F1]}}{\text{peak vGRF of the right leg [F2]}}$$

$$\mathrm{SIt} = \frac{\text{vGRF of the left leg at } t \text{ [F3]}}{\text{peak vGRF of the right leg [F2]}}$$

where t is the time point when the vGRF of the right leg reached the peak (Fig. 3).

The SI provides a quantitative measure of the asymmetry of loading between the two lower limbs, with the SIt providing a measure of the asymmetry when the vGRF of the non-operated leg (or right leg in the control group) reaches a peak. The SIt also provides a measure of the