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DOES SYMMETRY OF LOWER LIMB KINETICS EXIST IN SITTING AND STANDING TASKS?

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This study compared sit-to-stand and stand-to-sit symmetry for total hip arthroplasty patients (n=40) and a control group (n=19). 3D kinematics and kinetics were recorded. A symmetry index was calculated for kinetics. T-tests were significant for hip and knee moments and powers, and extension sum of moments for sit-to-stand, and for hip extension moment and power for stand-to-sit. THA patients mainly rely on their non-operated limb to perform the sit-to-stand task. There was less asymmetry during the stand-to-sit tasks, were found significant. This study underlines the presence of asymmetrical kinetics in THA patient for these tasks, and demonstrated that sit-to-stand is more sensitive to asymmetry. These results should be considered in rehabilitation programs, and consequently allow these patients to return to a more active lifestyle.

KEY WORDS: Total hip arthroplasty, kinematics, kinetics, symmetry, sit-to-stand, stand-to-sit.

INTRODUCTION: Total hip arthroplasty (THA) is known to relief pain and allow patients to regain mobility. While gait is an important task to assess, other daily functional tasks are also important for the autonomy of patients. One of these tasks is rising up from a seated position (sit-to-stand), and it's opposite (stand-to-sit). These tasks are repeated numerous times each day (Morlock et al., 2001), and have the potential to be more difficult to achieve, as a greater range of movement at the lower limb articulations is necessary. Earlier studies looking at how THA patients execute these tasks revealed that they tend to apply more force onto their non-operated leg, as demonstrated by an asymmetry in the vertical component of the ground reaction forces (Talis 2008). However, the ground reaction forces only represent the total amount of force applied to the ground, and we therefore cannot identify which articulation is compensating and causing this asymmetry. For example, Gilleard and colleagues (2008) found no significant differences in ground reaction force in a group of young healthy women, but then found asymmetry for certain kinetics variables such as frontal plane knee and ankle peak moments, as well as transverse plane hip, knee and ankle peak moments. While Miki and colleagues (2004) found no significant differences in pre- or postoperative gait parameters (cadence, stride length and step length) in a group of THA patients, they observed asymmetry in sagittal plane hip range of motion and pelvic tilt, up to 12 months after their surgery. The comparison of the kinetics variables during the sit-to-stand and stand-to-sit tasks will allow us to identify which lower limb articulations present asymmetry, and address these differences in post-operative rehabilitation programs.
The purpose of this study was to compare post-operative symmetry in kinetics of THA patients to those of an age- and weight-matched control group during a sit-to-stand and stand-to-sit task. It was hypothesized that THA patients would exhibit higher levels of asymmetry then the control groups during both tasks.

METHODS: A total of sixty participants between the ages of 50 and 75 years were recruited for the two groups (Table 1). The THA patients either had a direct lateral or anterior surgical approach. They were excluded if they had prior lower limb surgery, presence of joint degeneration at other articulations, or any condition affecting their balance (i.e. stroke). We could not use, because of a technical error, the data from one of the control participants. Patients were assessed at 307 ± 98 days post-surgery.
A total of 45 markers, with 20 for the lower limbs, were strategically positioned on the participant's body following a modified Helen Hayes markerset (Miki, et al., 2004). The participants wore skin tight clothing in order to reduce soft tissue artefact. The three-

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dimensional markers were tracked at 200 Hz with a nine-camera motion analysis system (Vicon MX, Vicon Motion Systems, Oxford, UK). Ground reaction forces were recorded at 1000 Hz with two force plates (AMTI OR-6-6-2000, Watertown, MA, USA) positioned side by side. The hip joint center was calculated with a commonly used regression technique (Davis III et al., 1991). The knee and ankle joint centers were located midline between their respective medial and lateral markers. Kinematics were computed accordingly to the Euler angle convention (Kadaba et al., 1990); kinetics through conventional inverse dynamics (Winter, 2005) using Vicon Bodybuilder software (Vicon Motion Systems, Oxford, UK).

Table 1
Participant demographics

Group	n	Male/female	Age (yrs) (SD)	BMI (kg/m^2) (SD)
THA	40	16/24	63.3 (6.9)	27.8 (4.9)
CON	19	10/9	63.5 (4.4)	24.9 (3.5)

Participants were asked to perform three trials of sit-to-stand and three trials of stand-to-sit on a bench adjusted to their tibial plateau height. They were instructed to position their arms slightly in front of them in order not to hide the pelvis markers. Peak values for each variable were extracted for each trial and then averaged for each participant. A symmetry index (*S*) was calculated for peak hip extension moment, peak hip abduction moment, peak knee extension moment, peak sum of moments (Winter, 1980), peak hip power, peak knee power and peak ankle power using the following formula:

$$S = |V_{no} - V_o| / (|V_{no}| + |V_o|) * 100\% \quad (1)$$

where V_{no} is the kinematic or kinetic variable of the non-operated limb and V_o of the operated limb. This formula, adapted from Talis and colleagues (2008), measures the symmetry of the variable, regardless of its direction. It was decided that a symmetry index lower than 10 would indicate that the participant demonstrated symmetry for the variable of interest.
Independent t-tests were performed on the symmetry indices and alpha was set at 0.05. For the variables that were found to be significantly different, the participants with a symmetry index superior to 10 were divided in two groups: favouring the operated (OP) or the non-operated (NO) limb. Control participants were divided similarly: favouring the matched dominant (OP) or non-dominant limb (NO).

RESULTS: The statistical analysis on the symmetry indices revealed several significant differences. For the sit-to-stand task, the THA group had a mean *S* significantly different from the control group for peak hip extension moment (p=0.003), peak knee extension moment (p=0.003), peak sum of moments (p=0.003), as well as peak hip (p=0.001) and knee power (p=0.015). The stand-to-sit showed fewer differences: significance was reached for peak hip extension moment (p=0.038) and peak hip power (p=0.048) (Table 2).
The frequency distribution of asymmetry shows that most THA patients favoured the non-operated limb for both tasks. During sit-to-stand, 60% and 63% of THA patients favoured the non-operated limb for peak hip extension moment and peak hip power, respectively. At the knee, the frequency dropped slightly to 45% and 43% for peak extension moment and peak power, respectively (Figure 1). During the stand-to-sit task, only the hip had significant differences between groups; 58% and 65% of THA patients favoured their non-operated limb for peak hip extension moment and peak hip power (Figure 2).

DISCUSSION: THA patient had significantly increased asymmetry in extension moment and power at both the hip and knee articulations for the sit-to-stand task, whereas only at the hip for the stand-to-sit task. This could be due to the fact that the latter task is less demanding. As demonstrated by Bergmann and colleagues (2001), stand-to-sit produced less contact forces at the femoral head than sit-to-stand, as measured with an instrumented prosthesis. The side preference for both tasks clearly shows that THA patients favour their non-operated side. This could be due to reduced muscle strength. While we did not measure this variable,

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Roy and colleagues (2007) showed a correlation with knee extensor strength and level of asymmetry between side in a group of individuals with hemiparesis. While this correlation was not shown at the hip, such a correlation could exist with our patient population as a surgical intervention was performed at that articulation.

Table 2
Results of independent t-tests and mean (SD) of the symmetry indices for the sit-to-stand and stand-to-sit tasks

Variable	Sit-to-stand p-value	Stand-to-sit p-value	Group	Sit-to-stand Mean *S* (SD)	Stand-to-sit Mean *S* (SD)
Peak hip extension moment*†	0.003	0.038	CON	9 (9)	10 (9)
			THA	21 (16)	18 (16)
Peak hip adduction moment	0.386	0.554	CON	37 (36)	47 (37)
			THA	45 (34)	39 (33)
Peak knee extension moment*	0.003	0.116	CON	9 (6)	12 (9)
			THA	17 (12)	18 (15)
Peak sum of moments*	0.003	0.148	CON	7 (5)	9 (6)
			THA	15 (11)	12 (10)
Peak hip power*†	0.001	0.048	CON	9 (8)	12 (8)
			THA	23 (13)	21 (18)
Peak knee power*	0.015	0.278	CON	9 (6)	14 (11)
			THA	17 (13)	17 (12)
Peak ankle power	0.205	0.797	CON	13 (17)	26 (20)
			THA	19 (14)	27 (21)

*Indicates a significant difference ($p<0.05$) for the sit-to-stand task
†Indicates a significant difference ($p<0.05$) for the stand-to-sit task

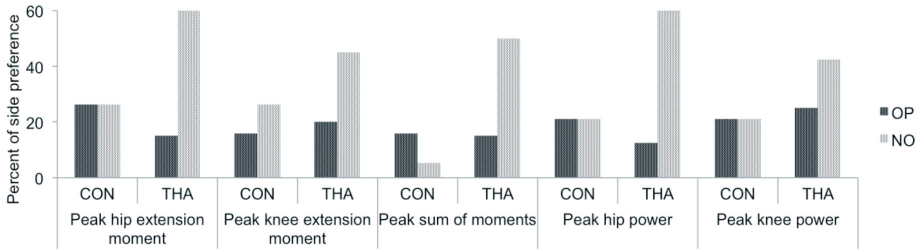

Figure 1: Side preference in percentage of frequency (OP: operated side for THA group and matched side for CON group; NO: non-operated side for THA group and non-matched side for CON group) for THA and CON groups for the sit-to-stand task for the variables with significantly different symmetry indices between groups.

The amplitude of moments was slightly lesser in the stand-to-sit task for our patients, as in Roy et al. (2007). This might explain why we didn't see any significant difference at the knee for this task. Mizner and Snyder-Mackler (2005) had similar findings for patient with total knee replacement: they showed reductions in both hip and knee extension moment at three months after surgery. Another potential explanation could be the lack of trust that THA patients have towards their prosthetic hip, even if pain is absent. They would then logically use primarily their sound side when performing bilateral tasks such as the ones we assessed. While we should try restoring symmetry for patients undergoing THA, we must keep in mind that a certain level of asymmetry is present in the general healthy population (Lundin et al., 1995) , independently of leg dominance (Hesse et al., 1996). However, too much asymmetry might cause muscle disuse and consequently muscle atrophy in the long term. It is also possible that pre-operative pain and reduced physical activity would have lead to altered patterns in activities of daily living, and consequently muscle atrophy. Regaining adequate muscle strength after surgery would therefore be more difficult.

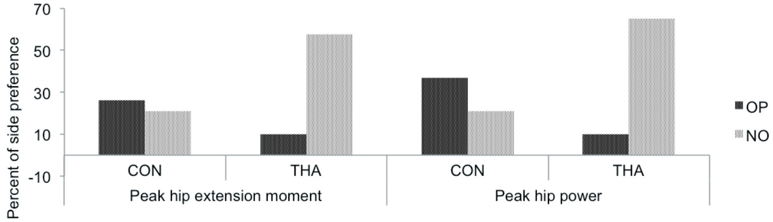

Figure 2: Side preference in percentage of frequency (OP: operated side for THA group and matched side for CON group; NO: non-operated side for THA group and non-matched side for CON group) for THA and CON groups for the stand-to-sit task for the variables with significantly different symmetry indices between groups.

CONCLUSION: This study identified asymmetrical patterns in THA patients in sit-to-stand and stand-to-sit tasks. Most favoured their non-operated limb for hip extension moment and power. However, asymmetry was seen at the knee articulation only for the sit-to-stand task, probably because this task is slightly more demanding. This study emphasizes the need for long-term rehabilitation program that would address these asymmetries.

REFERENCES:

Bergmann, G., Deuretzbacher, G., Heller, M., Graichen, F., Rohlmann, A., et al. (2001). Hip contact forces and gait patterns from routine activities. *Journal of Biomechanics, 34*(7), 859-871.

Davis III, R. B., Õunpuu, S., Tyburski, D., & Gage, J. R. (1991). A gait analysis data collection and reduction technique. *Human Movement Science, 10*(5), 575-587.

Gilleard, W., Crosbie, J., & Smith, R. (2008). Rising to stand from a chair: Symmetry, and frontal and transverse plane kinematics and kinetics. *Gait Posture, 27*(1), 8-15.

Hesse, S., Schauer, M., & Jahnke, M. T. (1996). Standing-up in healthy subjects: Symmetry of weight distribution and lateral displacement of the centre of mass as related to limb dominance. *Gait and Posture, 4*(4), 287-292.

Kadaba, M. P., Ramakrishnan, H. K., & Wootten, M. E. (1990). Measurement of lower extremity kinematics during level walking. *Journal of Orthopaedic Research, 8*(3), 383-392.

Lundin, T. M., Grabiner, M. D., & Jahnigen, D. W. (1995). On the assumption of bilateral lower extremity joint moment symmetry during the sit-to-stand task. *Journal of Biomechanics, 28*(1), 109-12.

Miki, H., Sugano, N., Hagio, K., Nishii, T., Kawakami, H., et al. (2004). Recovery of walking speed and symmetrical movement of the pelvis and lower extremity joints after unilateral THA. *Journal of biomechanics, 37*(4), 443-455.

Mizner, R. L., & Snyder-Mackler, L. (2005). Altered loading during walking and sit-to-stand is affected by quadriceps weakness after total knee arthroplasty. *Journal Orthopaedic Research, 23*(5), 1083-90.

Morlock, M., Schneider, E., Bluhm, A., Vollmer, M., Bergmann, G., et al. (2001). Duration and frequency of every day activities in total hip patients. *Journal of Biomechanics, 34*(7), 873-881.

Roy, G., Nadeau, S., Gravel, D., Piotte, F., Malouin, F., et al. (2007). Side difference in the hip and knee joint moments during sit-to-stand and stand-to-sit tasks in individuals with hemiparesis. *Clinical Biomechanics, 22*(7), 795-804.

Talis, V. L., Grishin, A. A., Solopova, I. A., Oskanyan, T. L., Belenky, V. E., et al. (2008). Asymmetric leg loading during sit-to-stand, walking and quiet standing in patients after unilateral total hip replacement surgery. *Clinical Biomechanics, 23*(4), 424-433.

Winter, D. A. (1980). Overall principle of lower limb support during stance phase of gait. *Journal of Biomechanics, 13*(11), 923-927.

Winter, D. A. (2005). *Biomechanics and Motor Control of Human Movement* (3 ed.). Hoboken, New Jersey: John Wiley & Sons, Inc.

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