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BIOMECHANICAL ANALYSIS OF THE SIT-TO-STAND MOVEMENT FOLLOWING KNEE REPLACEMENT: A CROSS-SECTIONAL OBSERVATIONAL STUDY.

¹Andy Kerr, ^{1,2}Angela H. Deakin, ^{1,2}Jon V. Clarke, ^{1,2}John M. Dillon, ¹Philip Rowe and ²Frederic Picard

¹Biomedical Engineering Department, University of Strathclyde, UK: email: a.kerr@strath.ac.uk

²Department of Orthopaedics, Golden Jubilee National Hospital, UK

SUMMARY

The sit-to-stand [STS] movement is a functional task that generates large forces across the knee. Only a few studies have reported biomechanical variables during this movement in post knee replacement patients and none have compared these variables between unilateral and bilateral sub groups. The aim of this study was to provide a biomechanical characterisation of the STS movement post knee arthroplasty and explore differences between bilateral and unilateral patients. Sixteen post arthroplasty patients [age 67.3 +/- 4.95, height, 164cm +/- 10.1, weight 80.8Kg +/- 15.0] were recruited from the same clinical site and underwent biomechanical analysis 7.9 +/- 6.92 months after surgery. Participants performed the STS movement from a set position without using their arms. Movement variables [movement time, joint rotation, peak force, loading symmetry and knee moments] were derived from a three dimensional motion analysis system. The bilateral group (n=7) performed the movement slightly faster (n/s) with better loading symmetry (mean 0.91 compared to 0.78) but smaller knee moments (mean 0.38 Nm kg⁻¹ compared to 0.49 Nm kg⁻¹) than the unilateral group (n=9). These results confirm patients with a knee replacement perform the STS movement differently to healthy older adults and provide comparisons between bilateral and unilateral patients.

INTRODUCTION

The sit-to-stand (STS) movement is a regularly performed functional movement [1] that is not only fundamental to upright ambulation but also to independent living [2]. The movement requires surprising large forces to execute, particularly at the knees where extensor moments can exceed 1Nm kg⁻¹ m⁻¹ [3], a value close to the maximum available knee extension strength for older adults [3]. Despite its importance and difficulty the STS movement has only been studied by a few researchers in total knee arthroplasty (TKA) populations. Su et al. [4] found TKA patients took longer to stand up from a chair than healthy participants of similar age and generated lower knee moments during the movement. Boonstra et al. [5] found both kinetic (loading symmetry) and kinematic (knee extension velocity) variables discriminated between healthy

and TKA patients. As bilateral involvement of the knee is common in osteoarthritis and always the case for Rheumatoid arthritis many patients will eventually have both knees replaced. Whether having both knees replaced confers biomechanical advantages over a single knee replacement has not been adequately investigated and may assist clinical decision making. Therefore, the purpose of this study was to report the biomechanical features (joint movement, performance time, loading symmetry and knee moments) of the STS movement following knee arthroplasty and secondly to document differences between those with one TKA (unilateral participants) and those with both knees replaced (bilateral participants).

METHOD

Design

This was an observational study of the STS movement in a cross section of post arthroplasty patients. Following ethical approval 16 participants [age 67.3±5.0, height 1.64m±0.10, weight 80.8kg±15.0, BMI 29.7±5.3] were recruited from the Golden Jubilee National Hospital following knee arthroplasty. Participants were recruited over a period of five months from follow up clinics. Nine participants were unilateral and seven were bilateral giving a total of 23 knees, nine of which were operated on using a navigated procedure and 14 conventionally. All participants underwent surgery within a year of the assessment [7.9 +/- 6.9 months] and had received a standard package of rehabilitation. Participants with co morbidities that could reasonably interfere with their physical function were excluded e.g. neurological conditions such as stroke and Parkinson's. Participants had a pre-operative Oxford knee score (measured on a scale of 12-60 with 12 being best and 60 being worst) of 37±5 (bilateral group) and 41±4 (unilateral group) and a 6 week post op Oxford scale of 29±4 (bilateral group) and 27±9 (unilateral group).

Measurements

Each participant attended the biomechanics laboratory at the University of Strathclyde. Performance of the STS movement was analysed with a three dimensional, eight camera motion analysis system (Vicon 612 System, Oxford Metrics, Oxford, UK) and two Kistler force plates (Kistler

Instruments Ltd, Hampshire, UK) Reflective markers (14mm in diameter) were located over anatomical points and clusters of markers were placed on the lower legs, thighs and sacrum. Kinematic data were collected at a rate of 120 Hz and kinetic data, from the force plates, at 120Hz. The resulting data allowed the digital construction of a three dimensional rigid body model of the lower limbs and pelvis allowing calculation of joint movement and loading.

Movement

Participants sat on a chair adjusted to knee height so that the lower limb joints were angled at 90 degrees with their feet in front of them on two separate force plates, this position was confirmed with real time visualisation of the 3D model. Participants stood up at a self selected speed with their arms crossed so that the use of upper limbs was removed as a confounding factor [5]. Participants performed the movement five times, with the first three successful attempts used for analysis.

DATA ANALYSIS

Using Polygon (Vicon, version 2.1) sagittal plane motion of the hip, knee and ankle were calculated for the whole movement duration. Maximum flexion for the hip and knee as well as maximum knee extension was recorded for comparison. The total excursion (maximum flexion to maximum extension) of each joint was used for analysis, for the hip this was from maximum flexion (typically around the point of seat-off) until maximal extension (typically at end of the movement). Vertical ground reaction forces were recorded, for each attempt, on both sides. A mean value of the peak, for each individual, was calculated and normalised to body weight, this was then used to derive a metric for loading symmetry. Using inverse dynamics knee moments were calculated from the rigid body model and forceplate data, the resulting peak moments were then normalised to body weight.

RESULTS

Duration

Movement duration for the whole group was similar to the values reported for healthy older people (Table 1).

Joint movement

While hip joint motion was similar across the whole group the bilateral group had, on average, greater knee flexion with similar knee extension ranges compared to the unilateral group (Table 1).

Table 1: Results for whole group, unilateral (operated only) and bilateral group (both knees), mean (SD).

	All	Unilateral (n=9)	Bilateral (n=7, knees=14)	Normal values
Duration (s)	1.65(0.49)	1.68 (0.52)	1.60 (0.48)	1.6
Hip motion (°)	26.9 (11.6)	26.4 (11.02)	26.8 (13.1)	
Knee flexion (°)	86.0 (13.5)	83.2 (14.9)	91.7 (10.19)	81
Knee extension n(°)	20.9 (11.1)	20.6 (12.2)	21.15 (10.1)	12
Symmetry (Ratio of peak vertical force)	0.84 (0.22)	0.78 (0.21)	0.91 (0.23)	1.00
Peak knee moment (Nm kg ⁻¹)	0.46 (0.16)	0.49 (0.18)	0.38 (0.05)	0.45

Kinetics

Force symmetry for the whole group was less than 1.0 however the bilateral group were, on average, more symmetrical in force application (table 1), though not statistically significantly so (p=0.26). Peak knee moments were generally greater for the operated knee of the unilateral group than for knees in the bilateral group, (Table 1).

DISCUSSION

This observational biomechanical study of the STS movement in post TKA patients, provides evidence these individuals perform this everyday task differently to healthy older adults and points to differences in the way the movement is performed according to whether one or both knees have been replaced. Time to perform the movement was comparable to older healthy populations [5] suggesting performance time may not, in itself, be a sensitive outcome measure for this population. Instead, knee angular displacement and loading symmetry may be more suited to evaluate the success of surgery. It would appear that unilateral patients favour their non operated side during STS (force ratio=0.78) compared to bilateral (0.91). These results can guide rehabilitation strategies. For example, continued asymmetry in knee loading for unilateral and bilateral patients may be modifiable through muscle strengthening programmes and movement practice. This paper has a number of limitations. The post-surgical observational design meant that neither a control group nor pre operative data were available for comparison. Nonetheless these data still provide useful information on the abilities of TKA patients to perform the basic task of rising from a chair. The small sample limited statistical comparisons and made a Type II error more likely, but the sample size is typical for biomechanical studies.

CONCLUSIONS

These results confirm that TKA patients can perform the STS movement in a similar time period as healthy older individuals but with some adjustment to the movement pattern e.g. asymmetrical loading of the knee joint. Participants who had both knees replaced performed the STS movement in a similar manner to older healthy participants, as reported in the literature, whereas unilateral patients tended to favour their non-operated side.

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