Clinical Biomechanics 43 (2017) 74–78

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Patients with total knee arthroplasty do not use all of their available range of knee flexion during functional activities

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ARTICLE INFO

Article history:
Received 20 May 2016
Accepted 30 January 2017
Available online xxxx

Keywords:
Knee arthroplasty
Kinematics
Flexion
Motion analysis
Function

ABSTRACT

Background: Recent research designed to improve outcome from total knee arthroplasty has included focus on strategies that increase the range of post-operative knee flexion. Patients with knee arthroplasty can now expect >100° of knee flexion following surgery, but it is not clear whether this improved range of motion facilitates outcome or whether patients take advantage of this range when completing daily functional activities. The aim of this study was to investigate the knee flexion angles used during daily functional activities that specifically required high degrees of knee flexion. It was hypothesised that patients with greater range of passive knee flexion would achieve higher degrees of knee flexion during functional activities.
Methods: Motion analysis was used to assess the maximum knee flexion of 40 patients with total knee arthroplasty and 40 control participants as they performed maximum flexion squatting and lunging activities.
Findings: Patients with knee arthroplasty used between 80.8 and 91.4° of knee flexion to complete these activities, which was 20 to 30% less than that used by the control participants. Patients with greater ranges of passive knee flexion had greater maximum knee flexion during functional activities. However, they used only between 68% and 77% of their full passive range when lunging and squatting.
Interpretation: The development of rehabilitation strategies that aim to increase weightbearing knee flexion capacity may be warranted to improve functional performance following total knee arthroplasty.

1. Introduction

Total knee arthroplasty (TKA) is an effective treatment option that consistently and effectively reduces pain and improves quality of life in people with severe knee osteoarthritis (OA) (Walsh et al., 1998; Woolhead et al., 2005). In recent years the prevalence of TKA has risen substantially, and in many countries the number of TKA procedures now exceeds that of total hip arthroplasty (Kurtz et al., 1783). The rising incidence of knee OA is likely to fuel demand for TKA in future years, and brings with it a likely change in patient demographics. Improved outcomes from surgery means that TKA is an increasingly attractive option for younger patients and more physically active patients with knee OA, and it is these patients in particular who expect to participate in more demanding physical activities post-operatively (Kurtz et al., 2009). Rather than being satisfied with relief from the pain associated with knee OA, patient satisfaction is increasingly being determined by patients' functional capacity following surgery. As such, there is a need to maximise function following surgery for outcomes to continue to meet patients' expectations.

Strategies to improve functional outcome from TKA have, in recent times, focused on increasing the range of post-operative knee flexion. Published literature details an abundance of studies that have evaluated modifications to existing TKA prostheses, or the development of new prostheses, with particular focus on the amount of knee flexion that is available after surgery (Sumino et al., 2011). Consequently, patients with modern TKA prostheses may now expect between 106 and 131° of knee flexion following surgery (Sumino et al., 2011). In patients, up to 140° of post-operative knee flexion has been reported, which far exceeds traditional expectations of TKA knee motion (Moynihan et al., 2010).

Despite these improvements, it is unclear whether greater post-operative knee flexion range has any benefit for patients' ability to complete functional activities of daily living. Studies investigating whether a greater range of post-operative knee flexion leads to greater patient satisfaction have reported either a very weak relationship or none at all (Meneghini et al., 2007; Narayan et al., 2009). Similarly, there is only minimal or weak evidence that patients with a greater post-operative range of motion perform better on objective assessments of function, such as the Timed Up and Go test (Mizner et al., 2005a; Zeni and Snyder-Mackler, 2010).

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http://dx.doi.org/10.1016/j.clinbiomech.2017.01.022
0268-0033/

A common assumption has been that increasing the available range of post-operative knee flexion means that patients will be able to flex to higher degrees when completing functional activities. Objective analysis of the knee flexion used during functional activities in patients with TKA is limited. However, research suggests that the amount of knee flexion used during functional activities post-operatively is not strongly associated with the amount of available knee motion. One study measured knee flexion motion with electrogoniometry and reported that the amount of knee flexion used by patients with TKA to complete ambulatory activities such as walking and stair climbing did not improve after surgery and was much less than that used by a healthy comparison group (Myles et al., 2002). Another study reported that when patients with TKA rose from a kneeling position, they did so with <90° of knee flexion (Nagura et al., 2005). In both studies, the authors suggested that knee flexion during the functional activities may be limited because of the weightbearing requirements of the tasks. It is also possible that because the activities performed did not require maximum knee flexion, participants in the research did not flex to their full capacity. To extend this work, it is necessary to investigate the relationship between available knee flexion (passive knee flexion range) and knee flexion achieved when undertaking more challenging functional activities, specifically those that require maximum possible knee flexion (active knee flexion range).

Therefore, the aims of this study were to (i) assess knee flexion angles during weightbearing activities that require maximum knee flexion in patients with TKA and (ii) to compare these to a cohort of unimpaired control participants of similar age. It was hypothesised that patients with a greater available knee flexion range would use more knee flexion during these activities.

2. Methods

2.1. Participants

Consecutive patients of a single experienced knee surgeon were assessed for eligibility to participate in this study. Patients were invited to participate if they had undergone total knee arthroplasty for knee osteoarthritis at least 12 months, and not >18 months prior to testing. Patients with other documented orthopaedic, neurological or visual disturbances that may affect gait, including joint replacements of the hips and ankles, were excluded. Patients with bilateral knee arthroplasty were included, provided the latest procedure was undertaken at least 12 months prior to testing. Of the 78 patients invited to participate in the study, 22 were excluded and 16 declined. The remaining 40 participants attended the institution's gait laboratory for assessment. All participants had received a fully cemented Genesis-II posterior stabilised prosthesis (Smith and Nephew, Memphis, Tennessee, USA) and the patella was resurfaced in all knees. Thirteen participants in the TKA group had received a previous arthroplasty in the contralateral knee and only the most recent TKA was included in the current analysis. There were no differences between the patients with unilateral TKA and those with bilateral TKA for any analysis, so the groups were combined to form a single TKA cohort.

The control group consisted of 40 participants recruited by advertisements at a local health sciences clinic. Control participants were assessed on the same inclusion and exclusion criteria as the TKA participants, except that control participants were not recruited if they had undergone any joint replacement surgery or reported any signs of lower limb osteoarthritis. All control participants were matched to the age (within 2 years) and sex of a member of the TKA group. A single limb of each control participant was used in the analysis and was determined by the limb of the matched TKA participant.

Ethical approval was granted from the Institution's Human Ethics Committee and informed consent was obtained from all participants.

2.2. Procedure

An 8 camera Vicon MX3 Motion Analysis System (Vicon, Oxford, UK) was used to collect kinematic data at a sampling rate of 100 Hz. Thirteen reflective markers of 14 mm diameter were placed over anatomical landmarks according to the Helen Hayes Marker System (Davis et al., 1991; Kadaba et al., 1989). Two additional markers were placed on the lateral aspect of the pelvis to enable recreation of the markers over the anterior superior iliac spine when these were occluded by excessive trunk or hip flexion. This procedure has previously been described in detail and validated for this population (McClelland et al., 2007). A knee alignment device was used to determine the centre of the knee joint during a static data calibration as described by Davis et al. (1991).

Data were collected when participants performed three commonly performed high-flexion activities that require maximum knee flexion under weightbearing conditions: (i) a standing squat (or deep knee bend) whilst weightbearing on both limbs, (ii) lunging in stride stance with the operated limb placed in front of the body, and (iii) lunging in stride stance with the operated limb placed behind the body. Participants were given standard instructions for each activity as summarised in Table 1 and were advised to practice each activity until they felt comfortable with the procedure before data collection commenced. A handrail was placed alongside the participant for safety, but trials in which the participant used the handrail were not included in the analysis. Following familiarisation, participants repeated each activity so that between 3 and 5 trials were collected with all necessary markers visible.

All TKA participants also attended a routine 12 month follow-up review with the operating surgeon. At this time, all participants completed the American Knee Society Score (Insall et al., 1989) which included measurement of the range of passive knee flexion using a standard goniometer.

2.3. Data analysis

Vicon Plug-In-Gait (Vicon, Oxford Metrics, Oxford, UK) was used to estimate the position of lower limb joint centres. Plug-In-Gait calculates lower limb joint angles based on the Euler principle where the joint angle is determined by the position of the moving distal segment relative to the proximal fixed segment. The maximum knee angles and the total time taken to complete each activity were extracted from each trial of each participant. These peak values were combined to form individual patient average values that were used to represent the maximum knee flexion of each task for each participant. Normal distribution of these data was confirmed using the Kolmogorov-Smirnov test.

The group average data for the peak values were compared between the patient and control groups using the independent samples *t*-test. The level of significance was set at $p < 0.05$. To assist in reader interpretation, all p values are reported and effect sizes were calculated using Cohen's d (1988). To investigate the relationship between amount of available knee flexion and the amount of knee flexion used during function, Pearson's r correlations were calculated between the passive knee flexion range, and the maximum knee flexion for all activities. All statistical analyses were completed using SPSS Statistics for Windows, Version 19 (IBM Corp. Released 2010, Armonk, NY, USA).

3. Results

3.1. Demographics

There were 22 females and 18 males in each group. For each group, the right limb was analysed in 24 participants and the left limb in 16 participants. The patients with TKA were tested on average 15.4 months (SD = 3.1) following surgery. There were no differences in age between groups (TKA average = 69.1 years, SD = 8.0; control average = 69.6 years, SD = 8.3). The groups were of similar height (TKA average =