Knee Joint Kinematics in Gait and Other Functional Activities Two Years after Knee Replacement: Is the Patients Function Normal?

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Introduction
To date there have been few follow-up studies which have attempted to quantify the functional ability of joint replacement patients during a range of functional activities. While much has been published indicating that knee replacement patients experience a reduction in pain and an increase in quality of life following knee replacement arthroplasty, little is known regarding their functional ability and their use of the replaced knee joint during every day movements. This study aimed to record the motion of the knee in the sagittal plane during functional activities carried out two years after surgery and to determine the normality of the movements produced by these patients.

Method
Flexible electrogoniometers (Nicol 1987, Rowe et al 1988) were used to record the sagittal motion of both knees during 11 functional activities (Figure 1). The electrogoniometers were bonded to flexible plastic extension pieces to minimise the effects of skin movement (Figure 1) and then attached to the sagittal surface of the skin above and below the knee using double side tape (Figure 2). Footswitches attached to the soles of the feet within the shoe at toe and heel were used to record the temporal parameters of movement.

Figure 1: Flexible electrogoniometer with flexible extension pieces.
Figure 2: Subject wearing flexible electrogoniometers across both knees and with footswitches attached to the soles of both feet.
The subjects performed a circuit of activities with the data recorded by a datalogger held in place by a purpose made bib (Figure 3). Subsequently the data was downloaded to a portable PC (figure 4).

20 normal elderly subjects (mean age 67 years) and 50 patients (mean age 70 years) 18-24 months post primary knee replacement for OA were recruited. The subjects were asked to perform eleven functional activities. All tasks were performed at the subject’s selected speed (free speed). The functions were:

1. Level walking : level walking;
2. Ascend slope : ascent of a 5 degree slope;
3. Descend slope : descent of a 5 degree slope;
4. Ascend stairs : ascent of a 20 step flight of stairs (165mm riser, 280mm tread);
5. Descend stairs : descent of a 20 step flight of stairs (165mm riser, 280mm tread);
6. Sit down low chair : descent from standing into a low chair (380mm high);
7. Sit to stand low chair : ascent from a low chair to standing (380mm high);
8. Sit down standard chair : descent from standing into a standard chair (460mm high);
9. Sit to stand standard chair : ascent from a standard chair to standing (460mm high);
10. Into Bath : from standing alongside bath, step in and sit down (590mm high);
11. Out of bath : from sitting, stand up and step out to stand alongside bath (590mm high).

The tasks were carried out using a circuit mapped out in and around the grounds of Princess Margaret Rose Orthopaedic Hospital Edinburgh. The data were downloaded from the datalogger at three points in the circuit. The data was then exported to Excel for Windows where all further data processing and analysis was carried out including interpolation using a specially written Turbo Pascal program. For each of the eleven activities a single cycle of the left and right legs were identified from the data using the footswitch and electrogoniometer information. Where a number of cycles were available such as during gait and stair negotiation a cycle was randomly selected from the middle of the data stream in order to avoid cycles during initiation or termination of the activity. Each cycle was then interpolated to give the joint angle at 100 percentage points throughout the cycle. These standardised cycles could then be amalgamated for the group to give the mean knee joint angle for the group throughout the gait cycle.

For each subject performing each function using each knee, the minimum knee joint angle used during the cycle and the maximum knee joint angle used during the cycle were calculated. These two values indicate the range of joint motion required to perform the functional activity. In addition the excursion of the joint during the function was calculated by subtracting the minimum value from the maximum values. The excursion indicates the amount of free knee joint angulation required to perform the task.
Results & Discussion

The mean excursion (and Standard Deviation) of the operated knee joint for the patient group in each functional activity is given in Table 1 along with those for the age matched normals. The knee motion used by the subjects was on average only 76% of that used by the age matched normals and ranged from 83% during gait to only 53% when getting out of the bath. The maximum excursion used by the patients was 76 degrees getting out of a standard chair as opposed to the 135 degrees used by the normals while exiting the bath. Patients had a passive range of motion of 98 degrees while normals had a passive range of 137 degrees. Patients used only 77% of their available range (98 degrees) which was itself reduced compared to the normals who utilised 98% of the available range (137 degrees). Independent student t-tests corrected using the method of Bonneferroni (P<0.004) indicated that the patients two years after operation showed significantly less excursion during all eleven functional activities than their age matched counterparts.

The results of this study indicate that the patients experienced a double loss in functional movement of the replaced knee two years following surgery. Their available range of motion was reduced by nearly 40 degrees and they also failed to use more that three-quarters of the available range during functional activity. One can conclude that the patients had a substantial and persistent loss of knee function following surgery. The data contained in this paper indicates that in order to carryout the functional activities evaluated the normal human knee requires a joint excursion of approximately 135 degree of flexion. If the use of a bath in a normal manner is not considered important then all the other functional activities can be achieved using 110 degrees of motion and the range required is from 0 degrees (the neutral position) to 110 degrees of flexion. These values would seem like suitable targets for the rehabilitation of the knee following injury or surgery.

<table>
<thead>
<tr>
<th>Function</th>
<th>16-24 months post-op patients</th>
<th>Age Matched Normals</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D</td>
</tr>
<tr>
<td>Level Walking</td>
<td>64.6</td>
<td>9.1</td>
</tr>
<tr>
<td>Stair Ascent</td>
<td>52.6</td>
<td>8.8</td>
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<tr>
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<td>Chair Ascent</td>
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<td>Chair Descent</td>
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<td>into Low Chair</td>
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<td>16.0</td>
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<tr>
<td>Out of Low Chair</td>
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<td>15.2</td>
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<tr>
<td>into Standard Chair</td>
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<td>13.3</td>
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<td>into Bath</td>
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<td>16.6</td>
</tr>
<tr>
<td>Out of Bath</td>
<td>72.9</td>
<td>19.9</td>
</tr>
</tbody>
</table>

Table 1: Excursion of the replaced knee and that of age matched normal subjects

The mean excursion (and Standard Deviation) of the operated knee joint for the patient group in each functional activity is given in Table 1 along with those for the age matched normals. The knee motion used by the subjects was on average only 76% of that used by the age matched normals and ranged from 83% during gait to only 53% when getting out of the bath. The maximum excursion used by the patients was 76 degrees getting out of a standard chair as opposed to the 135 degrees used by the normals while exiting the bath. Patients had a passive range of motion of 98 degrees while normals had a passive range of 137 degrees. Patients used only 77% of their available range (98 degrees) which was itself reduced compared to the normals who utilised 98% of the available range (137 degrees). Independent student t-tests corrected using the method of Bonneferroni (P<0.004) indicated that the patients two years after operation showed significantly less excursion during all eleven functional activities than their age matched counterparts.

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References
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