INTRODUCTION

Orthopaedic devices, such as hip and knee replacements, have generally been designed to accommodate the range of motion (ROM) required for activities common in Western cultures, including walking, stair climbing, and rising from a chair (Mulholland and Wyss, 2001). Accepted treatment of severe bone afflictions, such as OA, is often rejected by people in non-Western cultures upon discovery that the range of flexion following treatment would not accommodate activities such as squatting, kneeling, and sitting cross-legged (Villar et al., 1988). A study by Noble and Weiss (2001) found that patients in North America requiring a total knee replacement would also like to be able to perform activities of daily living (ADL) of high ROM, such as squatting while gardening. Unfortunately, they are rarely able to perform activities requiring a ROM of over 100° postoperatively. Furthermore, little is known about the forces and moments that a device would be required to withstand at these extreme ranges of motion. The purpose of this study is to collect kinematic and kinetic data at the hip, knee, and ankle joints during squatting, kneeling, and cross-legged sitting activities from subjects in India, representing an ethnic group where high ROM in ADL is important.

METHODS

Thirty subjects above the age of forty (20 male, 10 female) were recruited for this study in Chennai, India. The average subject age was 48.2 years (SD 7.6), average height was 158.6 cm (SD 7.5), and average weight was 57.1 kg (SD 10.2). Each subject was asked to perform 6 trials of each of the following activities that they carried out on a regular basis: squatting with heels up (i.e. balanced on flexed toes), squatting with heels on the ground (i.e. foot flat), kneeling with ankles dorsiflexed, kneeling with ankles plantar-flexed, and sitting cross-legged. Kinematic data was collected using the Fastrak® by Polhemus with four sensors placed at the foot, shank, thigh, and sacrum. A non-magnetic force plate (AMTI) was used to simultaneously collect ground reaction forces during each trial. From the synchronized data, an inverse dynamics approach using a link-segment model was used to calculate the floating axis angles, joint reaction forces and moments at the ankle, knee, and hip. Each trial was split into two phases: getting into activity position and returning to a standing position. Each phase was normalized to a 100% cycle.

RESULTS AND DISCUSSION

From Table 1, it is apparent that knee range of motion can easily exceed 150° of flexion during the activities studied. Maximum hip flexion values reached 120° for several subjects in various activities; however, the overall mean ROM angles are lower due to the high variability between subjects.

Table 1 Maximum Joint Range of Flexion (SD) for Several Activities of Daily Living in India.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Squatting Heels Up [26]</td>
<td>36 (10)</td>
<td>154 (10)</td>
<td>99 (30)</td>
</tr>
<tr>
<td>Squatting Heels Flat [26]</td>
<td>35 (10)</td>
<td>157 (6)</td>
<td>94 (24)</td>
</tr>
<tr>
<td>Kneeling with ankles dorsiflexed [26]</td>
<td>37 (10)</td>
<td>155 (9)</td>
<td>77 (36)</td>
</tr>
<tr>
<td>Kneeling with ankles plantar-flexed [6]</td>
<td>33 (7)</td>
<td>144 (13)</td>
<td>62 (16)</td>
</tr>
<tr>
<td>Sitting Cross-legged [26]</td>
<td>30 (11)</td>
<td>150 (8)</td>
<td>87 (35)</td>
</tr>
</tbody>
</table>

* The number of subjects for the hip range of flexion differs from the number of subjects for the ankle and knee range of flexion for the following activities: squatting heels up [n=25], kneeling with ankles dorsiflexed [n=24], and sitting cross-legged [n=23].

Interestingly, only 6 of 30 subjects were comfortably able to kneel with ankles plantar-flexed; this may be attributable to religious customs in this region of India. Sources of error associated with the application of the rigid body model used to calculate the kinematics include soft tissue movement and shifting of the sensors.

A typical plot of one phase of an individual activity in a single plane is shown in Figure 1. The plot illustrates the knee flexion and corresponding extension moment required to rise to a standing posture from the squatting with heels flat position. When the flexion angle begins to decrease, a characteristic peak moment appears. This demonstrates the dynamic forces required to accelerate the body upwards.

![Figure 1 Knee Flexion Angle ± SD and Extension Moment ± SD](image)

Figure 1 Knee Flexion Angle [n=26] and Extension Moment [n=22] during rise to stand from Squatting Heels Flat position.

SUMMARY

For the 5 prescribed activities, mean hip and knee flexion ranges commonly exceeded the ranges of motion typically allowed by most currently available joint replacements. It is essential to know the forces and moments that occur at the joint under high range of motion conditions in order to design and test prosthetic joints that will accommodate these extreme angles.

REFERENCES


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