

***IN VIVO* KNEE LOADING MEASURED BY AN INSTRUMENTED TOTAL KNEE REPLACEMENT DURING ACTIVITIES OF DAILY LIVING**

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INTRODUCTION

The knee sustains large contact forces over a broad range of flexion angles. The flexion angle where the largest forces occur during specific activities is an important consideration for understanding both normal and pathological conditions, since the position of the tibial-femoral contact is related to the activity, the phase of the activity, and knee flexion angle (Dyrby and Andriacchi, JOR 2004, Andriacchi and Dyrby, JBiomech 2005). Variations in the thickness of healthy knee cartilage suggests that in regions of habitual loading, stance phase knee flexion during walking, shows thicker regions of cartilage and thinner regions where it is less likely to be loaded (Andriacchi TP et al. 2004). The relationship between knee loads at high flexion angles is also an important consideration. For example, the incidence of osteoarthritis is substantially higher (15% to 30%) in workers who performed deep knee bends as part of their job, than in the general population (Felson et al. 2000). Thus, when analyzing the influence of knee loading on disease processes or in evaluating design criteria for total joint replacement it is important to consider specific activities. The overall goal of this study was to examine the relationship between activity, load, and flexion angle where maximum load occurs for walking, stair ascending and descending, chair rising and sitting, squatting and golf swing.

METHODS

A custom-designed instrumented knee prosthesis was implanted in the right knee of an 81-yr-old male (170 cm, 633 N). The subject performed a number of activities of daily living: walking, chair sit to stand and stand to sit, ascending and descending stairs, squatting, and a golf swing. Kinematic data were collected using an optoelectronic motion capture system (Qualisys). The knee flexion angle was calculated for the stance phase of each activity. The instrumented knee transmitted the compressive load from 4 uniaxial load cells embedded in the tibial component (D'Lima DD et al. 2005). The total force, the sum of all four load cells, was normalized to body weight (Bw). The range of knee flexion angles when the total compressive force exceeded 1, 1.5, 2 and 2.5BW were identified for each activity. We chose a range of force values based upon commonly seen ranges reported during the activity of walking. The maximum value (2.5 BW) was based upon a sub-maximal force seen during self selected normal walking.

RESULTS AND DISCUSSION

The activities were grouped into three categories based on knee flexion angle at peak loading (Figure 1). First, for habitual loading, walking, there was moderate load-low flexion angles. Next, stair activities and

golf had high load-moderate flexion. Finally, squatting and chair activities had moderate load-high flexion. The maximum compressive load was seen during stair ascent (3.6BW). Max load occurred at considerably different flexion angles, 8.5° for walking to 92° for squat (Figure 1).

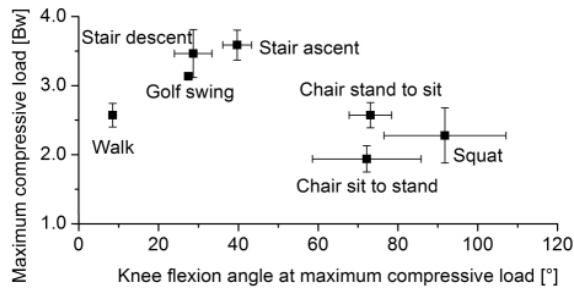


Figure 1: Max compressive load and the knee flexion angles at which they occur for each of the selected activities (± 1 std dev).

The ranges of knee flexion angles for large compressive loads varied for the activities (Figure 2). Activities that produced similarly high loads (2 to 2.5BW) occurred at different flexion ranges. For example, 2BW was produced at flexion range of 8° to 17° for walking while for squatting 2BW occurred over the 55° to 112° range (Figure 2). The results of this study showed that the knee is exposed to a wide range of peak loads and positions. In addition, within each movement, moderate to high loads are observed over substantially different ranges of flexion angles.

The loads and flexion angles can contribute to the limited lifetime of current implant designs. Cultural and activity related requirements to the function of joint replacements even at extreme angles such as squatting have led to the design of newer and improved joint replacements. However, to date joint *in-vivo* loads during these activities were largely unknown.

While the results of this study were based on a single subject, the relative loads across activities and associated flexion angles likely reflect a broader population. These loading conditions at specific angles of flexion give insight into the loading condition that could influence cartilage maintenance (Andriacchi et al 2004, Felson et al, 2000). Similarly, new TKR designs should consider these load-angle relationships for specific activities.

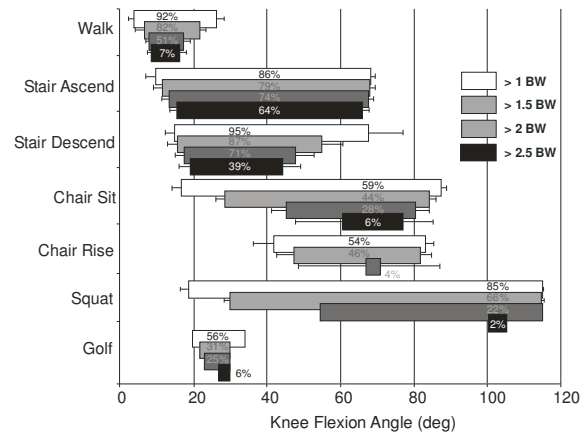


Figure 2: Range of flexion angles for activities with total compressive forces exceeding 1-2.5BW (± 1 std dev). Percentage of stance phase above these values is embedded in each bar.

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