PASSIVE RESISTANCE TO KNEE MOTION FOLLOWING TOTAL KNEE ARTHROPLASTY

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INTRODUCTION

Numerous studies have found complaints of knee stiffness in individuals post knee replacement surgery [1]. When patients complain of joint stiffness, from a biomechanical perspective, what they may be experiencing is an increase in passive resistance to knee motion. This passive resistance to motion, or passive moment, has not been quantified in this population. The focus of the current research was, therefore, to quantify passive knee resistance in Total Knee Arthroplasty (TKA) patients. Results of this work will help determine if mechanical stiffness underlies patient complaints of knee stiffness. Additionally, as the passive moment contributes to the net moment at a joint, better understanding of the effects of TKA on passive knee resistance may add to current understanding of knee moment changes in this population.

METHODS

Six individuals, an average of 32 months post TKA (range: 19 – 72 months; age: 70.67 ±10.5 years), were examined in this study. Their results were compared to 6 age matched controls (age: 69.7 ±4.4 years) with no history of lower limb arthritis or serious lower extremity injury.

Passive knee moment data were collected using a protocol modified from that of Reiner and Edrich [2]. With subjects in a seated position the experimenter slowly moved the knee from a flexed position to full extension and back again. The force required to move the knee through range was recorded using a loadcell attached just above the ankle malleoli using a custom designed ankle brace. The loadcell was mounted such that it measured forces exerted perpendicular to the long axis of the shank. Three trials were collected in two different hip positions: 90º flexion (sitting) and 180º (supine lying).

Three-dimensional knee joint kinematics were recorded during this motion using an Optotrak (NDI, Waterloo, ON) active marker system. The kinematics of a 2-segment (shank and thigh) lower limb model were determined using marker data from rigid plates that were affixed to both the shank and thigh. Each plate held three infrared emitting diodes securely fastened at mid-segment level. Singular value decomposition was employed during processing to reduce error due to skin movement artifact. Electromyography (EMG) was used to monitor quadriceps and hamstrings muscle activity during the motion to ensure motion was truly passive in nature.

Force and kinematic data were combined as per Reiner and Endrich [2], to determine the passive moment at the knee during the motion. The moment calculated using the force data consisted primarily of moment due to gravity and passive moment (inertial effect could be ignored due to the slowness of the motion). The equation below was used to separate these components and determine the passive moment.

$$M_{pas} = Fl - mgl_{CoG} \cos(\theta)$$

Where g is acceleration due to gravity, and θ is the angle between the shank and the left horizontal. Resulting passive moment curves were spline fit so they could be averaged over similar joint angles. A fourth order polynomial was then fit to these moment-angle curves. This polynomial was then differentiated to determine the passive knee stiffness at each of the two hip angles tested.

RESULTS and DISCUSSION

Excessive EMG during the flexion portion of the passive motion meant only the extension phase was analysed. As patients and controls varied with respect to the range of knee motion covered, all data were truncated (15º-55º). Patients and controls exhibited similar trends in passive knee moment, with greater resistance to knee extension while in a seated position and greater resistance to knee flexion when supine. Generally, however, passive moment values for patients were biased toward the flexor moment portion of the curve. The average

passive knee moment – angle relationship at the two hip angles examined is illustrated in Fig 1. Analysis of stiffness values showed no significant differences in stiffness between patients and controls over the knee range examined.

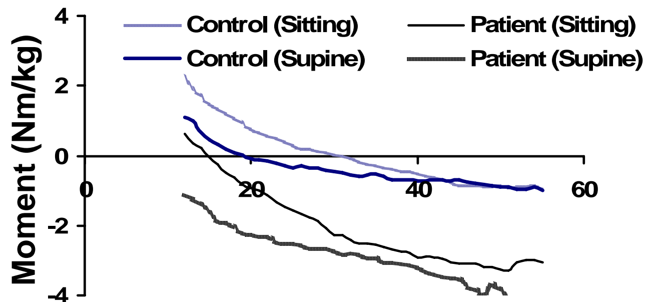

Figure 1: Passive moment for patients and controls. Horizontal axis represents examined knee range of motion (15º-55º of knee flexion). Average data based on data from all patient or control trials in the seated or supine position. (+ moment is flexion).

The current study represents the first attempt to quantify *in vivo* passive knee stiffness in this population. Results showed that the passive moment-angle relationship for both patients and controls followed expected patterns, suggesting no dramatic changes in the passive characteristics of replaced joints. For the small group tested, however, there does appear to be some difference in the magnitude of passive resistance following joint replacement.

One trend of interest was that, at both hip angles tested, patients exhibited greater passive knee moment than controls. The primary resistance to motion during knee motion was extensor in origin. Two possible sources of this extensor resistance exist: either it was produced by muscle activation or it came from passive tissues. Since EMG activity was monitored to ensure that minimal activation occurred, the latter reasoning is most likely true. There are several possible factors that may contribute to this increased midrange resistance. All patients in the study exhibited deficits in active knee flexion (107º ± 10º). While this degree of knee flexion enabled participants to perform the tasks examined, it was substantially less then typical maximum knee flexion (~140º). While patient characteristics (i.e. preoperative knee range and adherence to post-operative physiotherapy programs) can affect post-operative knee flexion, the factor which seems to have received the most attention is post-operative tibio-femoral kinematics [3,4]. Many investigations have determined that tibio-femoral kinematics differ post knee replacement. While the specifics of these differences vary depending on the type of prosthesis used, Victor and Bellemans [3] suggest that abnormalities in femoral rollback, femoral external rotation and posterior condylar offset can all result in decreased knee flexion post-TKA. It could be argued that alterations in tibio-femoral kinematics would invariably affect resistance to knee motion. It was hypothesized that this was the case in the current study, and that the increased resistance to motion observed in patients in the 15º to 55º range of knee flexion was due to alteration in tibio-femoral joint kinematics. Alternatively the increased passive resistance could also have been due to tension in passive tissues. This was unlikely, however, because in this range of knee motion, there would be minimal stress placed on passive tissues [5].

Due to the limited knee range of motion tested and small subject numbers, further research is needed to confirm the findings of this research. At this point, however, the current work provides a firm basis on which to build additional studies of this nature.

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