Joint Replacement Assessment – Team D
Team Members: Tony Kao, Tim Lane, Emma MacDonald, Taylor Mitchell, Hunter Read
Department of Mechanical Engineering, University of Kentucky, Lexington, KY

Background

Total Knee and Total Hip Replacements are two of the most significant medical advances of the 20th Century. These medical breakthroughs have allowed patients who have worn or damaged joints to be replaced with new metal or polymeric components, alleviating pain and restoring mobility to the patient. With these procedures being as successful as they are, it is no surprise that the demand for Total Knee and Total Hip Replacements is rapidly increasing. This increase in demand is due largely to the increasing age of the population in the form of the baby boomer generation. In 2013, there were 332,000 Total Hip Replacement procedures performed and 719,000 Total Knee Replacements performed.* As a result of such demand these two procedures are the leading contributors to escalating health care costs in the US, with a Total Hip Replacement cost ranging from $11,000-$126,000** and a Total Knee Replacement ranging from $22,611-$70,000***

*CDC.com
**CBSNews.com
***Kneereplacementcost.com

Figure 1: The image above shows a visual representation of knee replacement hardware that has been surgically installed. Image from: Dr. David Pienkowski

Problem Statement

With the increase in cost and demand of joint replacement surgeries the question currently at the forefront of everyone’s minds is “are the quality of patient’s lives really being improved?”. While there are currently methods to evaluate the success of joint replacement surgeries, these methods are perturbing, or invasive, and the patient is aware of the testing. The problem with this is there is a bias being introduced into the data that must be removed in order to objectively evaluate the success of joint replacement procedures. What then should be measured to determine the success of a Total Hip and Total Knee Replacement and how can the measurement data be obtained while being undetectable to the patient?

Current Technology

Currently there are facilities that are used with the medical field to evaluate the success of a patient’s recovery from a total hip or knee replacement. These facilities are generally referred to as Gait Labs, and contain advanced measurement devices that are used to obtain measurements such as angular movement of the replaced joint and force plates to obtain measurements of weight distribution. The issue with facilities such as these are that these tests to obtain the measurements are invasive to the patient and require the patient to be aware of test, there are perturbing tests. For instance, the primary method to obtain a measurement for angular motion is to use sophisticated motion analysis devices that require the patient to wear leotards with sensors on them in order to digitally map and measure movement. Weight distribution as previously mentioned is measured by making patients stand in various positions on force plates in order to obtain weight measurements. While these systems are quite useful to quantify patient recovery, they require a great deal of involvement from the patient. It is because of this high level of involvement from the patient that introduces bias into the data and causes the data to be skewed.

Metric: Force Distribution

Another parameter that could be measured that would be useful in assessing the success of a Total Hip or Knee Replacement is how reliant a patient is on their arm strength to sit down or get up from a chair. This metric works under the assumption that pain is inversely related to weight distribution. Patients who are experiencing more pain in a lower extremity used in the action of sitting down or standing up is more likely to be reliant on their arms to propel them downward or upward. Thus, through the use of strain gages, a Data Acquisition System and signal conditioning a chair could be developed to measure how reliant a patient is on their arm strength over recovery time. Using this data a steady trend should be identified that over time the patient should exert less force on the chair arms, indicating increased use of their legs to sit down and stand up.

Current State of Project

Currently the frame material of the chair, 80/20 extruded aluminum, has been cut to link as being assembled into the chair frame. Once the frame has been constructed the strain gages will be attached at specific and predetermined locations and hooked up to a DAQ. The strain gages will be tested to ensure that they are obtaining reasonable and useful data. This data will be processed using known signal conditioning techniques as well as mechanical design equations to determine the forces on various members of the chair. Upon ensuring that the strain gages are obtaining correct data ME412 Team D will begin working closely with a group of Computer Science Engineers in order to create a custom DAQ system for the force sensing chair.

Prototype Design

Figure 4 below shows a CAD model of the planned architecture for the chair that will be used to measure force distribution. This chair was specifically designed with hip and knee replacement patients in mind as the chair sits slightly higher than standard chairs to avoid irritating the newly replaced joints. Additionally the arms of the chair are designed to be circular so that there is only a single point of contact for patient’s to grab when either sitting down or standing up. By having only one point on the arms to grab this will help to normalize the data the strain gages are obtaining, as if the arms are grabbed at different points the data obtained by the strain gages will vary and cause inconsistencies in data interpretation.

Current Technology

Figure 2: The image above shows a gentleman walking in a gait lab where his movements are being measured. http://www.mdpi.com/1424-8220/11/1/207

Figure 4: Frame design of prototype force sensing chair

Figure 4 below shows a CAD model of the planned architecture for the chair that will be used to measure force distribution. This chair was specifically designed with hip and knee replacement patients in mind as the chair sits slightly higher than standard chairs to avoid irritating the newly replaced joints. Additionally the arms of the chair are designed to be circular so that there is only a single point of contact for patient’s to grab when either sitting down or standing up. By having only one point on the arms to grab this will help to normalize the data the strain gages are obtaining, as if the arms are grabbed at different points the data obtained by the strain gages will vary and cause inconsistencies in data interpretation.

Current State of Project

Currently the frame material of the chair, 80/20 extruded aluminum, has been cut to link as being assembled into the chair frame. Once the frame has been constructed the strain gages will be attached at specific and predetermined locations and hooked up to a DAQ. The strain gages will be tested to ensure that they are obtaining reasonable and useful data. This data will be processed using known signal conditioning techniques as well as mechanical design equations to determine the forces on various members of the chair. Upon ensuring that the strain gages are obtaining correct data ME412 Team D will begin working closely with a group of Computer Science Engineers in order to create a custom DAQ system for the force sensing chair.