EXAMINING THE KINEMATICS OF THE KNEE DURING A SIDE STEP CUTTING TASK USING THE HELICAL AXIS METHOD

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INTRODUCTION

Knee injuries, particularly anterior cruciate ligament (ACL) injuries, are a common and potentially disabling sports related injury. Of the 80,000 annually reported ACL injuries, 70% are non-contact ACL injuries. Non-contact ACL injuries occur 5-7 times more frequently in females than males[1]. An example of a non-contact movement that may cause ACL injury is the side-step cutting task commonly performed in sports such as soccer and basketball.

In motion analysis, a common method used to study and understand these types of motions is Euler angles. Although this method is more clinically relevant, it may not appropriately describe 3-D motion due to the non-vectorial behavior of 3-D rotations [2]. Another method used to analyze 3-D motion data is the Helical Axis (HA). The main advantage of using the helical axis technique is that it provides information about the actual axes of rotation in a joint which cannot be obtained using Euler angles [3]. It has been stated that the helical axis or instantaneous axis of rotation of the knee joint is one of the most significant parameters quantifying these motion characteristics [4].

METHODS

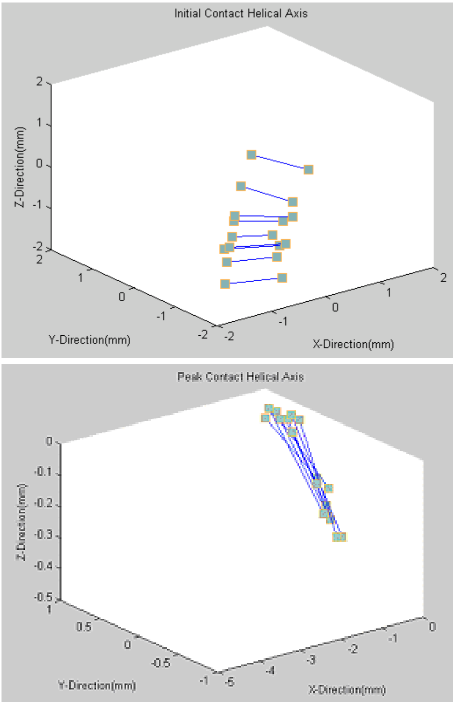
The kinematic data studied in this work consisted of the stance phase of an unanticipated side step cutting task. Subject data was obtained from 9 female NCAA Division 1 soccer players. The subjects were of an average age, height and mass of 19.3±0.9 years, 1.68±0.05m, 61±8.4kg, respectively. All of the kinematic data was captured using a Vicon Motion System (Vicon-UK, Oxford, UK) in the Motion Analysis Laboratory at Old Dominion University with an IRB-approved protocol. The subjects were presented with an image of a rolling soccer ball which cut across the display screen thereby indicating to the subject to perform a side step cut in the direction of ball motion.

Using Visual 3D (Vis3D) (C-Motion Inc., Germantown, MD), Euler angles and the net rotation about the helical axis decomposed into all three directions (x, y and z) of the body fixed axis of the tibia measured with respect to the femur were calculated and exported for the right knee. The Euler angle data were exported using an order of rotation (XYZ) consisting of flexion/extension followed by add/abduction and concluding with internal/external rotation. The rotation matrix and translation vector were also exported from Vis3D and used to determine the unit vector and a point on the helical axis using the method developed by Spoor [5] in a custom written program in MATLAB (The Mathworks, Natick, MA). Another custom program was used to plot the helical axis at initial contact and peak knee flexion for each subject. The same program was used to plot both the Euler and helical angles for each of the planar motions mentioned in a similar manner as Woltring [2].

RESULTS AND DISCUSSION

The helical axis at initial contact was found to be oblique indicating a combination of all 3 planar motions in the task. The helical axis at peak knee flexion is extremely oblique for all nine subjects (Figure 1). This indicates that all three types of planar motion are heavily involved in this complex motion at this specific time frame. The Euler and decomposed helical angles are similar in the sagittal and transverse planes (Figure 2).

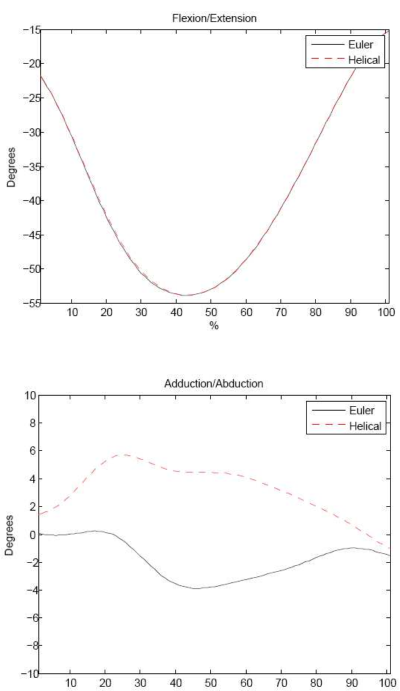
Side step cutting, in comparison to gait, is a more complex task involving large coupled motions. Analysis of the orientation of the helical axis during a flexion/extension motion in unconstrained cadaver

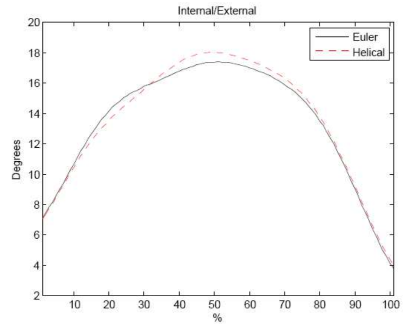


(a)

(b)

Figure 1: Helical axis orientation at a) initial contact and b) peak knee flexion





(c)

Figure 2: Euler & Helical angles for (a) flexion/extension (b) add/abduction and (c) internal/external rotation.

knees[4] were determined to be parallel to the trans-epicondylar axis. This same result was not seen in the side-step cutting task due to the coupled motions in all three planes. When comparing the Euler and decomposed helical angles, a high correspondence exists in flexion/extension yet there is variability in the other two motions particularly that of add/abduction, this variability was also observed in the coronal and transverse planes during gait [2].

The results presented here compared with an in vitro study designed to simulate knee flexion during gait demonstrate that the orientation of the helical axis (i.e., the axis of the rotation of the knee) varies with different motions. These results have implications in computational modeling and clinical treatment. Specifically, in dynamic modeling, the motion of the knee is typically defined as a one degree of freedom motion; however these data show that a one-degree of freedom motion is not sufficient in modeling complex knee. Additionally, with further study, this change in the orientation of the helical axis could provide orthopedic surgeons and rehabilitation specialists insight into how to operatively and non-operatively treat athletes who frequently perform complex motions, such as cutting tasks.

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