A Primer for Understanding Joint Kinetics

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Intended Audience:
- Clinicians responsible for interpreting motion analysis data.
- Engineers interested in developing innovative methods for analyzing human movement.

Prerequisite Knowledge:
- Familiarity with the use of joint forces, moments and powers in movement analysis.
- Familiarity with the standard equations of motion ($\Sigma \tau = I \alpha$ $\Sigma \mathbf{F} = m\mathbf{a}$).
- Basic algebra and trigonometry.

COURSE OUTLINE

I Introduction

The purpose of this course is to provide a review of the mathematical techniques used to derive kinetic data and to present implications that the mathematical techniques can have in data interpretation.

The course will begin by introducing the equations of motion ($\Sigma \tau = I \alpha$ $\Sigma \mathbf{F} = m\mathbf{a}$) and will demonstrate how they have been used in clinical biomechanics to determine joint forces, moments and powers. The equations of motion will first be applied in the more traditional inverse dynamics approach. A second method using generalized coordinates will be introduced. This method directly couples the equations in order to determine the influence that the moment at one joint will have on the other anatomical segments. Although the generalized method has been used extensively in computer simulation and surgical decision making models, it has not been widely taught in post-graduate motion analysis programs.

Finally, the implications of data interpretation using both approaches will be discussed. This discussion will include data from clinical cases as well as their application in computer simulations.

From this tutorial, the participant will learn to use the generalized form of the equations of motion to derive the simple relationships between joint kinetics and kinematics and thus be better equipped to understand and interpret their current motion analysis output. In addition, because this approach serves as the foundation for computer simulation, the participants will be better prepared to understand the result of surgical decision making models.

II Traditional form of the equations of motion as used for determining joint kinetics

Most commercial motion analysis software uses the inverse dynamics approach to generate kinetic information including joint forces, moments and powers. A link segment model with rigid body segments is typically assumed. To compute kinetics, the position and orientation of each of the segments must be known, as well as the accelerations, anthropometric measures

and external forces, i.e. ground reaction forces.

There are some limitations to interpreting data generated in the traditional method. Specifically, some problems arise in determining the true role of the joint moments, forces and powers in generating motion. A computer simulated case will be introduced and joint kinetics computed by inverse dynamics will be interpreted.

References:

Davis, R.B., Ounpuu, S., Tyburski, D., Gage, J.R., *A Gait Analysis Data Collection and Reduction Technique*, Human Movement Science 1991; 10: 575-587.

Winter, D.A., Biomechanics and Motor Control of Human Movement, John Wiley & Sons, 1990.

III Coupled dynamics - Generalized coordinate form of the equations of motion as used for determining joint kinetics

An overview of what generalized coordinates are and why they are helpful. Generalized coordinates are a common engineering method used to reduce the equations of motion to one independent variable for each degree-of-freedom in a link model.

During this section, the equations of motion will be derived for a simple two-link planar model using generalized coordinates. This example will be then used to illustrate the inherent relationships between joint kinetics and kinematics and demonstrate how each joint moment will produce accelerations at all of the joints in the body.

The resulting form of equations will be then be examined for their significance in understanding clinical motion analysis data. This technique will be applied to the computer simulation previously presented and reviewed in further detail to demonstrate the differences between the two sets of kinetic data.

References:

Zajac, F.E., Gordon, M.E. *Determining Muscle's Force and Action in Multi-Articular Movement*, Exer. Sport Sci. Rev 1989; 17: 187-230.

Nikravesh, P.E. Computer-Aided Analysis of Mechanical Systems. Prentice Hall, 1988.

IV Clinical case and examples

A clinical case will be used to compare the traditional and generalized methods. The clinical case will demonstrate how the generalized method can be used to directly measure the compensatory mechanics used in a patient with lower extremity weakness.

V Discussion and questions

We hope to initiate discussion among participants who are involved in clinical interpretation of kinetic data as well as those involved in forward dynamic modeling. We invite participants to bring examples of their work for discussion by the group.

Tutorial handouts available via ftp

The handouts for the tutorial, which derive the mathematical relationships used for computing joint kinetics, can be obtained in advance of the meeting via ftp. (The handouts will also be distributed at the start of the tutorial.)

The handouts (which are Microsoft Word Documents) can be obtained from the ftp site **bmli1.cc.nih.gov**

To download the document via Web Browser:

* Use browser (Netscape or Internet Explorer) to connect to ftp://bmli1.cc.nih.gov/
* Select the directory pub/tutorial/
* Select the file handout.doc to download to your machine

To download the document via ftp:

- From the dos or unix shell type: **ftp bmli1.cc,nih.gov**
- login using the account name **anonymous**
- use your email address as the password
- One you are logged in set the mode to binary by typing: **binary**
- Set the directory to pub/tutorial by typing: **cd pub/tutorial**
- Download the file handout.doc by typing: **get handout.doc**
- Logout out by typing: **quit**

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