INTRODUCTION

Human gait is typically studied with clinical observation or in a gait laboratory. The first approach is rapid but subjective and limited. The second, while it is experimentally rigorous and provides voluminous amounts of quantitative data, is time consuming and expensive.

Computer simulation may offer an alternative approach for both the analysis of normal gait as well as in modeling the effects of changes in joint mechanics, muscle strength, and orthotics use. Current simulation techniques, however, are limited in their ability to model the complex analysis necessary to study gait when it is altered by an abnormal joint or the compensatory actions of the body and other joints.

Numerical presentations alone do not permit an intuitive understanding of modeling trials. Graphical presentation, on the other hand, has much to offer in that it presents the overall pattern of gait in a manner that is easy to assimilate.

We investigated the feasibility of a new approach to the graphical presentation of gait modeling that is sensitive enough to demonstrate the effects of abnormal joints, strength, or the presence of orthotic devices.

METHODS

Our simulation model consists of 8 rigidly-linked masses which represent the upper and lower torso, thighs, shanks, and feet. The “diseased” or “abnormal” joint is located at hip, knee, or ankle of one lower extremity. The motions of the lower torso and other extremity are defined in the same manner as those of the normal walking.

Four models were studied: a zero moment joint (ZMJ) which transmits forces to adjacent links but does not generate a moment during stance phase; a passive element joint (PEJ) which has a spring at the abnormal joint; a constrained range joint (CRJ); and a partial moment joint (PMJ) which produces moments smaller than those of a normal joint.

The JAVA network language is used for the simulation program, and VRML is used for representing three-dimensional (3-D) graphics on a WWW Internet browser.

RESULTS AND DISCUSSION

A simple model with a ZMJ at the hip during level walking produces moments at the remaining joints of the affected lower extremity that are much greater than those of normal walking. A reduction in gait speed and step length lessens their magnitude. However, with a ZMJ at either the hip or knee, modified gait patterns alone could not reduce all compensatory actions to acceptably small levels: the magnitude of moments at the lowest joint 4-12 times larger than normal.

More complex models produced more realistic compensatory actions. For example, changing from a ZMJ to a CRJ+PMJ combination produced distinctive changes in the

![Figure 1](image1.png)

(a) Walking with a CRJ and PMJ at the right hip. Walking speed, $V$, is 0.4 m/s; step length, $S_X$, is 0.29m, and an open stance (i.e., each lower extremity at the heel contact is 5° lateral to the vertical line from the hip joint to the floor). (b) Walking with ZMJ at right hip under normal walking conditions, $V$=1.5m/s and $S_X$=0.74m. Lengths are normalized by leg length.

![Figure 2](image2.png)

Three-dimensional dynamic model simulations are attractive because they provide predictive information about a system that often can not be obtained experimentally in a colorful and realistic manner accessible to anyone through the Internet.

REFERENCES
