EXAMINATION OF THE QUASI-STATIC ESTIMATION OF RESULTANT JOINT MOMENTS

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INTRODUCTION

Resultant joint moments are frequently computed for the analysis of human movement. A complete inverse dynamics analysis of a movement requires the computation of segment center of mass accelerations and segment angular accelerations (dynamic approach). Computation of derivatives from inherently noisy displacement data is an ill-posed problem (Lanshammar, 1982), meaning the moments can be strongly influenced by errors in derivatives values. During the ground contact phase of a movement the moments at the joints can be estimated by ignoring the inertial contributions, and the weights of the segments. The moment is computed by taking the product of the magnitude of the ground reaction force vector and the perpendicular distance between the joints position and the ground reaction force vector originating from the center of pressure. This approach will be referred to as the static approach, it has been used for the analysis of human movement (e.g. Arborelius et al., 1992; Schultz et al., 1992).

Wells (1981) compared the dynamic with the static approach for computing moments during walking. The deficiency in this evaluation was that there were no criteria with which to compare the computed moments, they were only compared with one another. It was the purpose of this study to compare the accuracy of the static approach with the dynamic approach using criterion data generated from a simulation model.

METHOD

A simulation model of vertical jumping was developed. The model was planar and consisted of four segments linked by frictionless pin joints. The segments were the foot, shank, thigh, and the HAT (head, arms, and trunk). The inertial properties of these segments were determined for a male subject 1.85m in stature with a body mass of 85kg. The equations of motion of the four-link system were integrated forward in time to determine the motion of the segments given the moments acting at the joints. The integration step was 0.0001 seconds. The moments at the joints were provided by actuators crossing the joints, with muscle like properties. The sequence of the actuator activations was selected to provide a maximum vertical jump.

White noise was added to the model determined displacement data. To mirror typical experimental protocols the noisy data was low-pass filtered using either a Butterworth filter or a spline. For both filters the amount of filtering was automatically selected using either an autocorrelation based procedure (Challis, 1999), or dynamic programming (Dohrmann and Busby, 1990). The filtered and differentiated data were used to compute the resultant joint moments. The percentage root mean squared difference (%RMSD) between the moments computed using either approach (dynamic and static) and the model produced moments were computed.

RESULTS

The kinematics and kinetics of the simulated jump were similar to those measured for experimental subjects (e.g. Challis, 1998). Quantitatively the results were similar whether the data had been filtered using the Butterworth filter or the spline so tables 1, 2 and 3 present only the results for the spline.

Table 1 - The %RMSD between the criterion moments and those computed using the dynamic approach.

Noise Level	*Ankle %RMSD*	*Knee %RMSD*	*Hip %RMSD*
σ=1.0mm	1.1	13.7	119.0
σ=2.5mm	1.7	15.8	118.6
σ=5.0mm	2.1	18.8	130.8

Table 2 - The %RMSD between the criterion moments and those computed using the static approach.

Noise Level	*Ankle %RMSD*	*Knee %RMSD*	*Hip %RMSD*
σ=1.0mm	4.2	6.0	20.4
σ=2.5mm	4.3	5.9	20.4
σ=5.0mm	4.3	5.9	20.5

Table 3 - The %RMSD between the moments computed using the dynamic and static approaches.

Noise Level	*Ankle %RMSD*	*Knee %RMSD*	*Hip %RMSD*
σ=1.0mm	4.1	14.7	61.4
σ=2.5mm	4.2	16.5	59.8
σ=5.0mm	4.1	14.7	61.4

DISCUSSION

For the ankle joint the dynamic approach was more accurate than the static approach, but for the other joints the static approach was more accurate. In effect ignoring the influence of the acceleration of the limbs on the joint moments was preferable to estimating them from noisy derivative data. Comparing static and dynamic moments is not a viable way of assessing the accuracy of the static approach (table 3).

A high-speed movement was selected to test the assumptions underlying the static approach, but it also served to highlight the problems in accurately estimating second derivatives for the dynamic approach. These results highlight the problems of accurately estimating resultant joint moments, and demonstrate that the static approach has some benefits. It should be anticipated that these results are most likely activity specific.

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