DETERMINATION OF OPTIMAL FILTER PARAMETERS FOR FILTERING KINEMATIC WALKING DATA USING BUTTERWORTH LOW PASS FILTER

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INTRODUCTION: Noise in biomechanical displacement data are often reduced by digital filter routines. In literature the cross-validated quintic spline from Woltring (1986) and the Butterworth low pass filter are commonly used. Challis (1999) recently suggested a method for determining the optimal cut-off frequency of Butterworth low pass filters. This method is based on a combination of residual analysis and autocorrelation. The optimization of the filter order, however, is not discussed by Challis. Thus the purpose of this study was to determine optimal filter parameters (frequency and order) of a Butterworth low-pass filter using the approach of Challis applied to a kinematic data set in walking.

METHODS: Challis (1999) showed that for white noise the value of the function A in

$$A = \sum_{L=1}^{m} R_{SS}(L)^2 \tag{1}$$

equation (1) which is the sum of the squared autocorrelation values $R_{ss}(L)$ over all lags L of the residuals of the raw and filtered signal is zero. This approach suggests the optimal cut-off frequency of a Butterworth filter with distinct order for the very frequency, where A yields a local minimum. To gain also information on optimal filter order the iteration process was expanded so that both, optimal filter frequency and filter order could be determined at the local minimum of A.

This algorithm was implemented into MATLAB and was applied to kinematic walking data. 22 students volunteered in this study and they were asked to walk on a ramp with 9 different gradients (-24 to +24°) giving a total data set of 198 trials. 2-D kinematic data of the right leg during one stance phase were collected, 7 body landmarks of the lower extremity and the shoulder were indicated with markers (about 1 cm diameter) and digitized manually (PEAK5).

RESULTS AND CONCLUSIONS:

The mean values of the optimal cut-off frequencies were determined between 6.5 and 7.0 Hz (Figure 1) matching well with frequencies suggested by Winter (1990), who reports that for heel and toe markers 99% of the signal power is contained below 7 Hz. Optimal filter order was found to be 2 for all markers in both dimensions. A cluster analysis showed no significant grouping of the cut-off frequencies by walking gradient or subjects, so it seems that the information on optimal cut-off frequencies is of more general nature.

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