CHARACTERISTIC FREQUENCIES OF HUMAN POSTURAL SWAY

S. Gürses*, S.T. Tümer**, B.E. Platin**, N. Akkas*
* Engineering Sciences Department, Middle East Technical University, Ankara/Turkey
**Mechanical Engineering Department, Middle East Technical University, Ankara/Turkey

Introduction
The human upright posture exhibits an everlasting oscillatory behavior of complex nature, called as the postural sway. Mechanisms responsible for these oscillations are recruited by the information coming from a variety of sensory events, which include proprioceptive, vestibular, visual and cutaneous receptors. These sensory modalities were experimentally shown to have different frequency bands (Ishida et al., 1997). The whole spectra of postural sway are further enriched by mechanical factors such as motions in different planes and their intercoupling.

The postural dynamics was investigated by many researchers; ranging from the use of parametric identification of a transfer function representing a PID-stabilized inverted pendulum model through a set of experimental results (Johansson et al., 1988), and the use of stochastic continuum models (Chow and Collins, 1995) to a random walk analysis of the center-of-pressure trajectories by using a unique non-linear model to describe their dynamics (Chiari et al., 2000).

The present research aims to explore the reasons for everlasting oscillations of human upright posture, by identifying characteristic frequencies of postural sway and their association with various sensory mechanisms, as well as by investigating the degree of chaotic behavior involved. For this purpose, along with experimental results, a series of simulations based on a non-linear model are also employed. This abstract reports the preliminary experimental results indicating the existence of some distinct frequencies, which characterize human postural sway in general.

Methods
During a biped stance, the feet of the subject apply distributed forces on the ground in three dimensions. The ground reaction forces supporting this distributed force system are measured by means of a force platform while a subject stands on it. The resultant of this force system consists of three force components and a moment about the vertical axis passing through the center of pressure.

Ground reaction forces and moments are measured with a Bertec force plate in the Biomechanics Laboratory of the Mechanical Engineering Department at the Middle East Technical University (METU). The force plate signals are first pre-amplified internally, then sent to an external amplifier in which a filter with a pre-set cut-off frequency of 500 Hz is employed. Filtered analog signals are fed to the computer after being digitized by an A/D converter (DAS 1202 Keithley MetraByte). Force-Plus ALPHA Version 1.00 software (Bertec Corp.) is used to manipulate the signals to obtain the ground reaction forces and moments at a sampling frequency of 25 Hz.

As the analysis is confined to the sagittal plane, variations of the horizontal frictional force (F_x) and the position of the center-of-pressure (CoPx) are used to identify the postural sway. One should note that two force components (F_x and F_z) and a moment (M_y) act on this plane; however, CoPx alone represents the combined effect of F_z and M_y (as CoPx = M_y / F_z).

Eight sets of 30-second time-records of F_x and CoPx are collected from each one of eight healthy subjects instructed to stand still in upright posture. In order to identify the characteristic frequencies and spectral patterns, fast Fourier transforms (FFT) of these time records are taken by using 1024 data points with added zeros after subtracting the mean values of signals. The inspection of the FFT patterns, especially the ones related to F_x, reveals that there exist at least two characteristic frequencies in the spectra with some considerable side-banded behavior (Figure 1).

The invariant system frequencies are also searched by a two-degree-of-freedom ANOVA. For both F_x and CoPx, the amplitudes corresponding to each sampled frequency in the spectrum of FFT’s are arranged as an 8x8 matrix, whose rows and columns are arranged to correspond to trials and subjects, respectively. The p-values of the Fisher indices are then calculated for the matrices, each corresponding to a sampled
frequency, for both $F_x$ and $\text{CoP}_x$. These indices for p-rows (intra-subject) and p-columns (inter-subject) of the ANOVA tables were plotted for $F_x$ and $\text{CoP}_x$ against frequency.

**Results**

In Figure 2, plots of the Fisher indices are presented for $F_x$, only. These plots indicate a high correlation between different tests for each subject at all frequencies, as expected. However, correlations between subjects are significant only at certain frequencies indicating the invariant sway frequencies for normal subjects. The analysis reveals that there exist at least six invariant system frequencies, which span in a range of 1-5 Hz.

**References**


**Acknowledgments**

Authors are thankful to Prof. Dr. Mehmet Çaliskan, Mechanical Engineering Department of METU, for his invaluable help during the preparation of signal processing protocols.

![Figure 1. FFT Pattern of $F_x$ for a Subject](image1)

![Figure 2. p-value of Fisher Indices of Combined FFT Results for $F_x$](image2)