THE HUMAN OPERATOR TRANSFER FUNCTION: IDENTIFICATION OF THE LIMB MECHANICS SUBSYSTEM

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In most studies of human manual control systems, the operator is characterized as a lumped, indivisible system, whose dynamics are linear and of low order. The objective of our research is to decompose the performance of the human operator in terms of the subsystems that determine the operator's responses in order to establish how the dynamics of these component subsystems influence the operator's performance. In the present experiment, the dynamic stiffness of the human elbow joint was measured at rest and under different levels of biceps muscle activation; this work forms part of the analysis of the limb mechanics subsystem.

The stiffness of the elbow joint was determined by subjecting the right wrist to stochastic position perturbations (S.D. 3mm, bandwidth of 100Hz) delivered by an electromagnetic linear motor (100 mm maximum linear displacement, peak static force 500 N). Subjects generated a target force (ranging from 0 to 150 N) during the perturbations, and were provided with visual feedback of the mean force produced.

The stiffness frequency response function was determined at each mean force level. These functions were calculated by Fourier transforming the stiffness impulse response functions. Figure 1 shows the stiffness frequency response functions obtained from a subject generating a mean force of 25N (thin line) and 150N (thick line). The increase in the low frequency stiffness with an increase in mean muscle activation level (as reflected in the mean force) is clearly evident. The figure also demonstrates that stiffness increases at higher frequencies. This essentially high-pass characteristic of the limb mechanics system is well-known. In Figure 2, a typical coherence function is shown. The decrease in coherence at higher frequencies is due, in part, to a loss in the signal-to-noise ratio caused by limitations in the bandwidth of the motors, whereas the loss of coherence at lower frequencies probably reflects the contribution of reflexes.

Figure 1

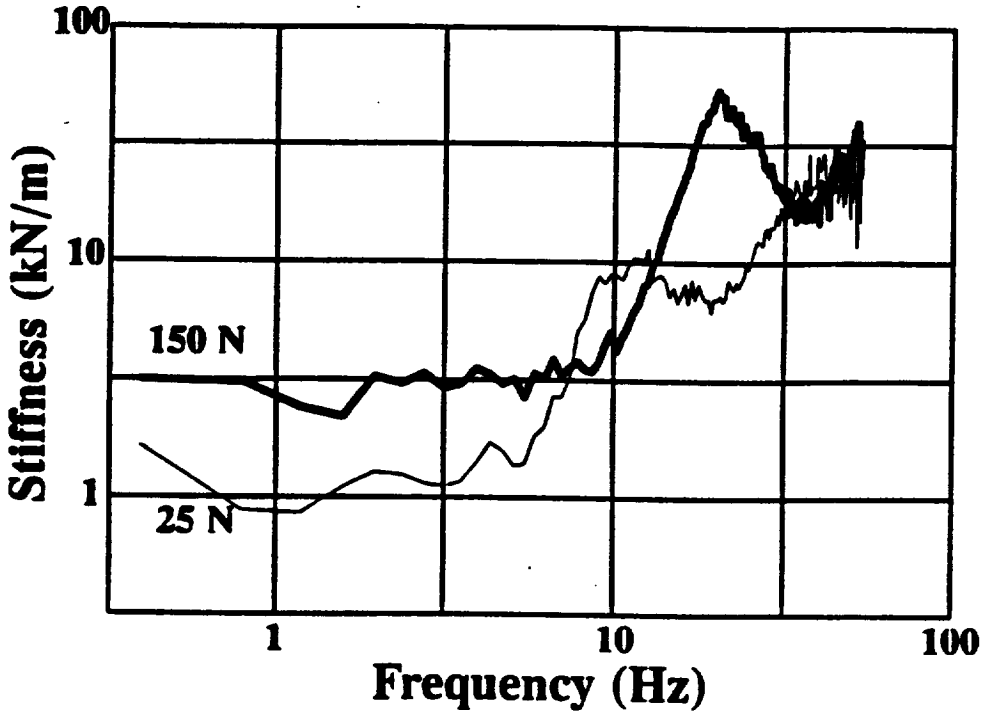

Figure 2