UPPER BODY JOINT COORDINATION UNDER VIBRATION

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Introduction

Whole body vibration is known to affect movement accuracy [1], however little is known about changes in the organization of movement and movement strategies used to limit the influences of perturbations. The specific aim of this work is to analyze the motion and coordination of upper body segments of seated operators performing reaching tasks under whole-body sinusoidal vibration exposure and simulated vehicle ride motion. The long-term objective is to model reach coordination and predict the dynamic behavior of the upper body motion under vehicle vibration exposure.

Method

The reach task consisted of pointing with the right hand index finger to targets located on touch screens placed in front of the subject, 45° overhead and 90° to the right in the mockup cabin of an HMMWV placed on a 6 DOF ride motion simulator. The task was performed under stable (no vibration) and vibration (sinusoidal vibration or simulated ride motion) conditions. A motion capture system was used to record kinematic data of reflective markers to recreate body link trajectories. Joint angles (torso, shoulder and elbow; Figure 1) were then computed using quaternions. Coordination between body links was defined as a) the joints angle-versus-angle relationships between the upper arm and lower arm, and b) the joint motion onset relationships between torso, upper arm and lower arm in the time domain.

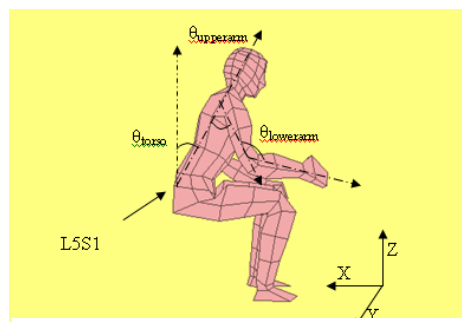


Figure 1. Angle definitions

Results

Angle–versus-angle relationships. The relationship between upper arm vs. lower arm angle and torso vs. upper arm angle for a far forward reaching movement in the stable (solid lines) and vibration conditions (dotted lines) are illustrated in Figure 2. Fig 2A compares the control condition with a 4 Hz lateral vibration while Fig 2B compares the control condition with a 6 Hz vertical vibration. It appears that under vibration exposure the reduced upper arm extension is compensated by an increase in torso flexion. This effect is seen in the last phase of the movements (encircled areas). In addition, the lower arm extension is delayed under 6 Hz vertical vibration (Fig 2B left panel).

Time of joint motion onset. The timing relationship between torso, upper arm and lower arm is largely a function of the target to be reached. Examples of delays between body links are illustrated in Figure 3. The control condition is compared to a 6 Hz vertical vibration for three

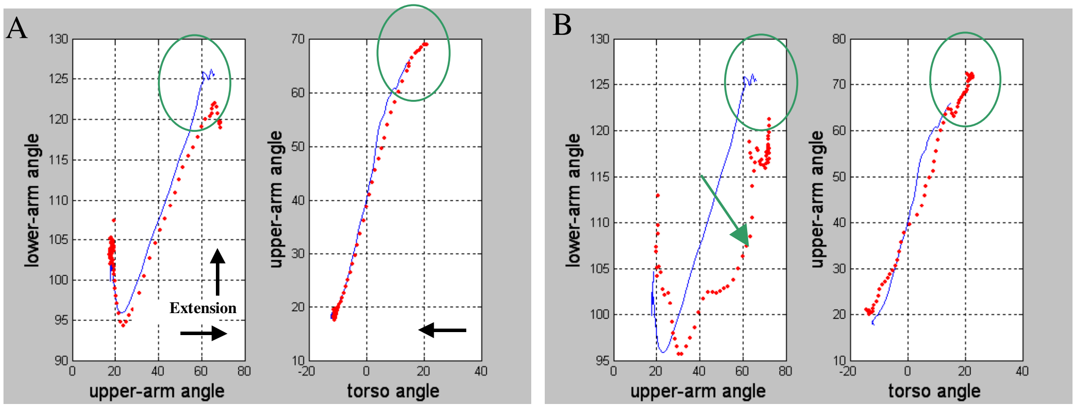
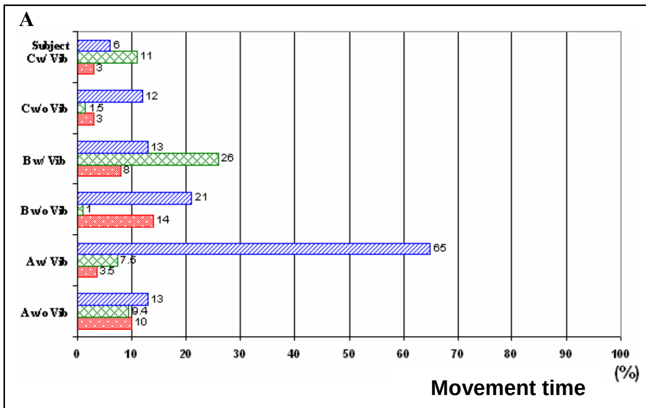


Figure 2. Angle-versus-angle relationships for a far forward reach in two vibration conditions. A: lateral direction, 4 Hz, 0.2g vibration. B: vertical direction, 6 Hz, 0.2g. [control: solid line; vibration: dotted line]

subjects reaching to a lateral target. For this target, the upper arm moves first in the control condition while the torso moves first under vibration exposure.



B

Without Vibration	With Vibration
Torso 1 (0) 2 (3) 3 (0)	Torso 1 (3) 2 (0) 3 (0)
Upper Arm 1 (3) 2 (0) 3 (0)	Upper Arm 1 (0) 2 (1) 3 (2)
Lower Arm 1 (0) 2 (0) 3 (3)	Lower Arm 1 (0) 2 (2) 3 (1)

Figure 3. Timing of movement onsets for a lateral near reach. A) movement onset times (torso: dotted bar; upper arm: bar with the x; lower arm: diagonal bar); B) order of movement onset.

Discussion

Overall the results indicate that the movement strategies (magnitude and timing of joint movements) change under vibration exposure; however, these strategies are dependent on movement direction. It is assumed that the forward flexion of the torso may be used to reduce the influence of vibration on the perturbation of the arm movement.

Reference

Gauthier, G.M., Roll, J.P., Martin, B., Harlay, F. (1981) Effects of whole-body vibration on sensory motor system performance in man. *Aviat Space Environ Med 52*(8): 473-479.