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EFFECT OF ARM SUPPORT ON FORCE AT A HAND-HELD JOYSTICK DURING EXPOSURE TO VERTICAL SEAT VIBRATION

G S Paddan & M J Griffin

Human Factors Research Unit, ISVR, University of Southampton, Southampton, SO17 1BJ, UK

ABSTRACT

The effect of no support, arm support, and wrist support on force transmitted to a hand-held joystick has been studied. Twelve male subjects sat on a rigid flat seat in a 'back-on' posture. The forearm was horizontal and the upper-arm vertical. Subjects were exposed to vertical vibration at frequencies below 10 Hz with a magnitude of 1.0 ms^{-2} r.m.s. Greater forces occurred in the fore-and-aft and the vertical axes at the joystick compared with the lateral axis. Arm support and wrist support resulted in lower vertical force transmissibilities compared to the no support condition.

1. INTRODUCTION

Hand-held joysticks are used in both stationary and vibration environments. The effect of whole-body vibration in transmitting force to a hand-held joystick has rarely been investigated. The effect of contact with an armrest was investigated in a study by Torle [1] involving 3 subjects exposed to vertical random 'gust' accelerations. Contact with the armrest reduced involuntary movements of the arm and improved tracking performance compared to the no armrest condition. McLeod and Griffin [2] found an arm support to be beneficial in reducing the effect of vibration on a hand-held joystick during exposure to vertical whole-body vibration. These two studies have shown that support for the arm affects the performance of tasks carried out using hand-held joysticks.

Paddan and Griffin [3] presented data on intra-subject variability and inter-subject variability in the transmission of fore-and-aft seat vibration to force at a hand-held joystick. Measurements of triaxial force at the joystick were reported for a situation in which there was no support provided for the arm. The effect of support for the arm was investigated in the experiment reported in this paper.

2. EQUIPMENT AND PROCEDURE

Forces in three orthogonal axes at the hand were measured using a joystick mounted on a Kistler 3-component quartz force transducer (type 9251A). The joystick consisted of a wooden dowel 28 mm in diameter and 130 mm long. The force signals were amplified using a Kistler charge amplifier type 5041C. Seat acceleration was measured using an Entran type EGCS-240-B-10D accelerometer.

A group of twelve male subjects took part in the inter-subject variability study (mean age 32 yrs, weight 71 kg, stature 1.79 m). All subjects were fit and healthy and complied with the medical contraindications specified in British Standard BS 7085 [4]. The subjects sat on a rigid seat (seat surface 480 mm above the moving footrest) in an upright comfortable posture with their backs in contact with the seat backrest (i.e. a 'back-on' posture). The seat backrest extended up to the subject's shoulders. The subjects were instructed to keep their upper arms vertical and their forearms horizontal (i.e. the included elbow angle was 90°) and apply a 'normal grip' to the joystick.

Three different supports for the lower arm were investigated: no support, arm support (forearm in contact with the seat from the elbow to the wrist), and wrist support (contact between the wrist and the seat). The arm support and wrist support were provided by rigid flat surfaces covered with a high stiffness rubber layer (approximately 1 mm thick). The wrist support was 50 mm wide and 70 mm long, and located 5 mm from the joystick so as to provide support for the hand at the metacarpal bones. The arm support was 50 mm wide and 390 mm long and provided support for the lower arm (i.e. ulna) from the carpus (wrist) to the elbow. Figure 1 shows a subject sitting with the three types of support for the lower arm and holding a force joystick. The joystick and supports moved with the same motion as the rigid seat supporting the subject. The subjects' arms were not in contact with the body. The order of presentation of postures was balanced across subjects.

Vibration was generated using an electro-hydraulic vibrator capable of producing vertical displacements of 1 metre. Vertical random vibration was presented over the frequency range 0.12 Hz to 10 Hz with a magnitude of 1.0 ms^{-2} r.m.s. Each subject was exposed to the same vibration three times: once with each of the three supports for the arm. Each vibration exposure lasted 120 seconds; all signals were acquired into a data acquisition and analysis system, *HVLab*, at a sample rate of 65 samples per second. The four signals (one of acceleration and three of force) were low-pass filtered at 15 Hz.

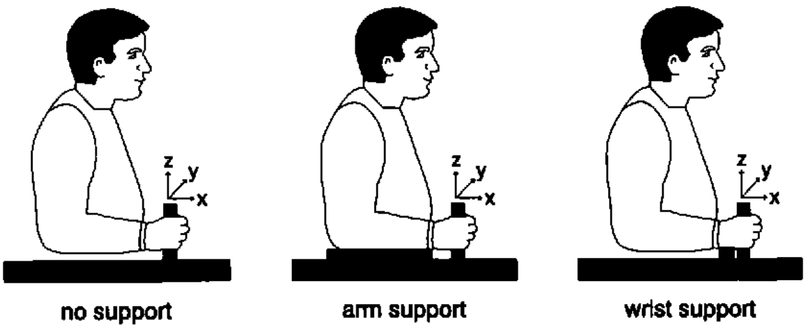

Fig. 1. Subject sitting with three types of support for the lower arm and holding on to a joystick.

3. ANALYSIS

The transfer function, $H(f)$, between seat acceleration and force at the joystick was calculated as the ratio of cross-spectral density of acceleration at the seat and force at the hand, $G_{af}(f)$, and the power spectral density of acceleration at the seat, $G_{aa}(f)$: $H(f) = G_{af}(f)/G_{aa}(f)$.

4. RESULTS AND DISCUSSION

The effect of support for the arm is shown in Figure 2 for all subjects and all three axes of forces at the hand. The greatest forces exerted by the hand as a result of the vibration were in the fore-and-aft and the vertical axes. Transmissibilities for force in the fore-and-aft axis show a peak at about 6 Hz with all postures of the arm: the effect of support for the arm was small in this axis. Transmissibilities for forces in the lateral and vertical axes show a decrease as support was provided for the arm and the hand.

The effect of support for the arm on the median transmissibilities of the twelve subjects is shown in Figure 3. The effect of arm support is different for the three axes of force: for the fore-and-aft axis the greatest force occurred with the wrist support whereas, for the lateral and the vertical axes, greatest forces occurred when no support was provided.

The acceleration at the hand (i.e. the joystick) was the same as the acceleration at the seat. The data therefore show the vertical 'apparent mass' of the hand with the different support conditions. For the no support condition, the subjects held the joystick and tended to support the whole arm on the joystick. Therefore, at low frequencies the ratio of vertical force to acceleration the joystick should correspond to the mass of the hand and the forearm. The median 'apparent mass' of the arm, at these low frequencies is seen to have been about 1.2 kg.

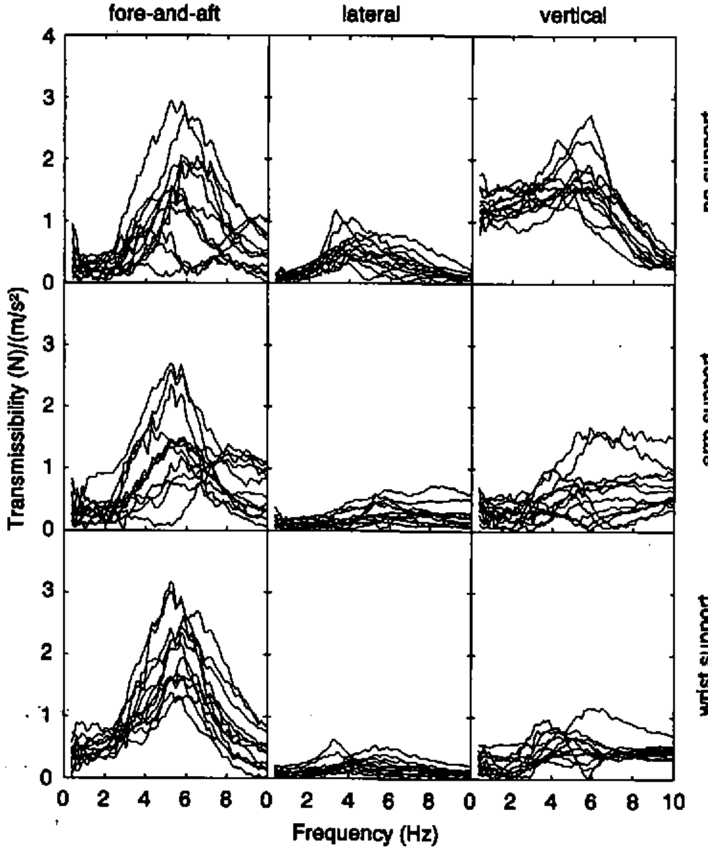

Fig. 2. Transmissibilities between vertical seat acceleration and triaxial force at the joystick for subjects sitting in a 'back-on' posture (0.127 Hz resolution, 64 degrees of freedom).

5. CONCLUSIONS

During exposure to vertical seat vibration, force at the joystick occurred mainly in the fore-and-aft and vertical axes. The main effect of providing support for the arm and the wrist was reduced force at the joystick in the vertical direction at frequencies below about 8 Hz. A peak in transmissibility for fore-and-aft force at the hand occurred at about 6 Hz. There was a large variation in response between subjects.

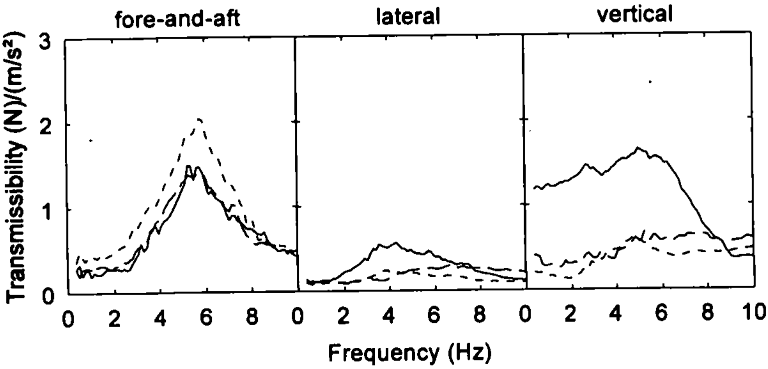

Fig. 3. Median transmissibilities between vertical seat acceleration and triaxial force at the joystick (———— no support; — — — arm support; ··············· wrist support).

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