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HUMAN RESPONSE TO VIBRATION

ABSTRACTS

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X. Wu, S. Rakheja and P.-É. Boileau 1999 *Society of Automotive Engineers, SAE Paper* 1999-01-1304. Dynamic performance of suspension seats under vehicular vibration and shock excitations. (13 pages, 15 figures, 2 tables, 17 references) (in English).
Authors' Abstract. A coupled human-seat-suspension model is developed upon integrating asymmetric and non-linear models of the cushion, suspension and elastic end-stops with a three-degrees-of-freedom biodynamic model of the occupant. The validity of the model is examined under harmonic and stochastic vibration excitations of different classes of vehicles, using the laboratory measured data. The suspension performance under continuous and shock excitations, assessed in terms of Seat Effective Amplitude Transmissibility (SEAT) and Vibration Dose Value (VDV) ratio, revealed that attenuation of continuous and shock-type excitations pose conflicting design requirements. It is thus proposed to develop suspension design for optimal attenuation of continuous vibration, while the severity of end-stop impacts caused by shock-type excitations be minimized through the design of optimal buffers. Two different optimization problems are formulated to minimize the SEAT and VDV ratios. The first optimization problem is solved to achieve optimal suspension stiffness and asymmetric damping properties, while the peak dynamic deflection is constrained to account for occasional end-stop impacts. The second optimization problem is solved to derive optimal properties of the end-stop buffers under large amplitude excitations. The results suggest that soft and lightly damped suspension with low degree of damping asymmetry coupled with low friction and large suspension mass can enhance vibration isolation performance. Thick and soft elastic buffers with nearly linear stiffness characteristics over a large deflection range reduce the severity of end-stop impacts. The proposed optimal design yields considerable reduction in both SEAT and VDV ratio response under selected classes of excitations.
Topics: Seating (suspension seats).

B. Drerup, M. Granitzka, J. Assheuer and G. Zerlett 1999 *European Spine Journal* **8**, 458–467. Assessment of disc injury in subjects exposed to long-term whole-body vibration. (10 pages, 8 figures, 6 tables, 28 references) (in English)
Authors' Abstract. Long-term exposure to whole-body vibration is known to increase the risk of low-back problems. The chain of events leading from repeated loading of the lumbar spine to back complaints and the exact nature of the vibration-induced damage are, however, obscure. Fluid in- and outflow as well as viscoelastic deformation are important aspects of the physiological function of the lumbar disc. Precision measurement of stature, termed 'stadiometry', has previously been applied in healthy subjects to document changes in disc height in relation to the load on the lumbar spine. The purpose of this study was to explore the relation between spinal loading and stature in a cohort of 20 subjects with long-term exposure to whole-body vibration. If the change of stature (and thus the change

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of disc height) caused by changes in spinal loading differed between exposed and normal subjects, this would point to vibration-induced changes in structure and material properties of the discs. For this purpose, four hypotheses were tested: (1) the viscoelastic deformation and fluid exchange of intervertebral discs during phases of spinal loading and unloading differ form normal; (2) the water content of lumbar discs of subjects exposed to long-term whole-body vibration deviates from normal; (3) the mean disc height of the lumbar spine depends on the total time of vibration exposure; (4) repeated loading influences trabecular bone density of vertebrae in the lumbar spine. A cohort of 20 operators of heavy earth-moving machinery was enrolled. Back complaints suspected to be due to long-term exposure (mean 17.6 ± 2.1 years) to whole-body vibration and application for early retirement were the selection criteria used. Change of stature during a regular 8 h shift and change of stature in standing, carrying and sitting activities were measured. The stadiometric investigations were supplemented by magnetic resonance imaging (MRI) of the lumbar spine to assess whether the water content of the discs exhibited deviations from normal. In addition, quantitative computed tomography (QCT) was performed to assess whether the trabecular bone density of the third lumbar vertebra deviated from normal. The results showed no significant differences in change of stature while standing, carrying or sitting between exposed machine operators and non-exposed operators. Likewise, MRI examinations revealed no significant differences in the water content of the disc averaged over the lumbar spine. In addition, QCT examinations revealed no significant difference in the trabecular bone density of the third lumbar vertebra. The study thus revealed no significant difference between a cohort with long-term exposure and non-exposed controls with respect to viscoelastic properties of discs as determined by stadiometry, average water content of lumbar discs and trabecular bone density of L3.
Topics: Injury and disease (whole-body); Physiological effects (skeletal).

W. E. Hoogendoorn, M. N. M. van Poppel, P. M. Bongers, B. W. Koes and L. M. Bouter 1999 *Scandinavian Journal of Work, Environment and Health* **25**(5), 387–403. Physical load during work and leisure time as risk factors for back pain. (17 pages, 0 figures, 4 tables, 108 references) (in English).
Authors' Abstract. This systematic review assessed aspects of physical load during work and leisure time as risk factors for back pain. Several reviews on this topic are available, but this one is based on a strict systematic approach to identify and summarize the evidence, comparable with that applied in the clinical literature on the efficacy of intervention for back pain. A computerized bibliographical search was made of several databases for studies with a cohort or case-referent design. Cross-sectional studies were excluded. A rating system was used to assess the strength of the evidence, based on the methodological quality of 28 cohort and a three case-referent studies and the consistency of the findings. Strong evidence exists for manual materials handling, bending and twisting, and whole-body vibration as risk factors for back pain. The evidence was moderate for patient handling and heavy physical work, and no evidence was found for standing or walking, sitting, sports, and total leisure-time physical activity.
Topics: Injury and disease (whole-body); Physiological effects (skeletal).

R. S. Kennedy, K. M. Stanney and W. P. Dunlap 2000 *Presence* **9**(5), 463–472. Duration and exposure to virtual environments: sickness curves during and across sessions. (10 pages, 3 figures, 3 tables, 35 references) (in English).
Authors' Abstract. Although simulator sickness is known to increase with protracted exposure and to diminish with repeated sessions, limited systematic research has been performed in these areas. This study reviewed the few studies with sufficient information

available to determine the effect that exposure duration and repeated exposure have no motion sickness. This evaluation confirmed that longer exposures produce more symptoms and that total sickness subsides over repeated exposures. Additional evaluation was performed to investigate the precise form of this relationship and to determine whether the same form was generalizable across varied simulator environments. The results indicated that exposure duration and repeated exposures are significantly linearly related to sickness outcomes (duration being positively related and repetition negatively related to total sickness). This was true over diverse systems and large subject pools. This result verified the generalizability of the relationships among sickness, exposure duration, and repeated exposures. Additional research is indicated to determine the optimal length of a single exposure and the optimal intersession interval to facilitate adaptation.
Topics: Motion sickness; Prevention; Exposure duration.

W. T. Lo and R. H. Y. So 2001 *Applied Ergonomics* **32**(1), 1–14. Cybersickness in the presence of scene rotational movements along different axes. (14 pages, 4 figures, 5 tables, 86 references) (in English)
Authors' Abstract. Compelling scene movements in a virtual reality (VR) system can cause symptoms and motion sickness (i.e., cybersickness). A within-subject experiment has been conducted to investigate the effects of scene oscillations along different axes on the level of cybersickness. Sixteen male participants were exposed to four 20 min VR simulation sessions. The four sessions used the same virtual environment but with scene oscillations along different axes, i.e., pitch, yaw, roll, or no oscillation (speed: 30°/s, range: $\pm$ 60°). Verbal ratings of the level of nausea were taken at 5 min intervals during the sessions and sickness symptoms were also measured before and after the sessions using the simulator sickness questionnaire (SSQ). In the presence of scene oscillation, both nausea ratings and SSQ scores increased at significantly higher rates than with no oscillation. While individual participants exhibited different susceptibilities to nausea associated with VR simulation containing scene oscillations along different rotational axes, the overall effects of axis among our group of 16 randomly selected participants were not significant. The main effects of, and interactions among, scene oscillation, duration, and participants are discussed in the paper.
Topics: Motion sickness (visual).

M. Bovenzi, C. J. Lindsell and M. J. Griffin 2001 *Occupational and Environmental Medicine* **58**(3), 185–193. Response of finger circulation to energy equivalent combinations of magnitude and duration of vibration. (9 pages, 2 figures, 3 tables, 27 references) (in English)
Authors' Abstract. Objectives: to investigate the acute response of finger circulation to vibration with different combinations of magnitude and duration but with the same "energy equivalent" acceleration magnitude according to current standards for hand-transmitted vibration. Methods—Finger skin temperature (FST) and finger blood flow (FBF) were measured in the middle fingers of both hands of 10 healthy men who had not used hand-held vibrating tools regularly. With a static load of 10 N, the right hand was exposed to 125 Hz vibration with the following unweighted root mean square (rms) acceleration magnitudes and durations of exposure: 44 m/s^2 for 30 min; 62 m/s^2 for 15 min; 88 m/s^2 for 7·5 min; 125 m/s^2 for 3·75 min; and 176 m/s^2 for 1·88 min. These vibration exposures produce the same 8 h energy equivalent frequency weighted acceleration magnitude ($\sim$ 1·4 m/s^2 rms) according to international standard ISO 5349 (1986). Finger circulation was measured in both the right (vibrated) and the left (non-vibrated) middle fingers before the application of the vibration, and during a 45 min recovery period. Results — The FST did not change during exposure to vibration, whereas vibration with any combination of

acceleration magnitude and duration produced significant percentage reductions in the FBF of the vibrated finger compared with the FBF before exposure (from − 40·1% (95% confidence interval (95% CI) − 24·3% to − 57·2%) to − 61·4% (95% Cl − 45·0% to − 77·8%). The reduction of FBF during vibration was stronger in the vibrated finger than in the non-vibrated finger. Across the five experimental conditions, the various vibration stimuli caused a similar degree of vasoconstriction in the vibrated finger during exposure to vibration. There was a progressive decrease in the FBF of both fingers after the end of exposure to vibration with acceleration magnitudes of 44 m/s^2 for 30 min and 62 m/s^2 for 15 mins. Significant vasoconstrictor after effects were not found in either finger after exposure to any of the other vibration stimuli with greater acceleration magnitudes for shorter durations. Conclusions—For the range of vibration magnitudes investigated (44–176 m/s^2 rms unweighted; 5·5–22 m/s^2 rms when frequency weighted according to ISO 5349), the vasoconstriction during exposure to 125 Hz vibration was independent of vibration magnitude. The after effect of vibration was different for stimuli with the same energy equivalent acceleration, with greater effects after longer durations of exposure. The energy equivalent acceleration therefore failed to predict the acute effects of vibration both during and after exposure to vibration. Both central and local vasoregulatory mechanisms are likely to be involved in the responses of finger circulation to acute exposures to 125 Hz vibration.

Topics: Hand-transmitted vibration. Physiological effects (vascular).

M. Bovenzi, F. Giannini and S. Rossi 2000 *International Archives of Occupational and Environmental Health* **73**, 519–527. Vibration-induced multifocal neuropathy in forestry workers: electrophysiological findings in relation to vibration exposure and finger circulation. (9 pages, 1 figure, 5 tables, 35 references) (in English)

Authors' Abstract. Objectives—to investigate neural conduction in the upper limbs of symptomatic forestry workers with and without exposure to hand-transmitted vibration. A further aim was to assess the possible relationships between vibration exposure, nerve conduction and finger circulation in the forestry workers who used chain saws. Methods: A detailed neurophysiological investigation was performed on the upper extremities of 20 chain saw workers, 20 forestry operators with heavy manual work but without vibration exposure, and 20 healthy male controls. All subjects were screened to exclude polyneuropathy. Measurements of sensory and motor nerve conduction (velocity and amplitude) were obtained bilaterally from the median, ulnar and radial nerves. To assess peripheral vascular function, the forestry workers underwent a cold test with plethysmographic measurement of finger systollic blood pressure (FSBP). In the chain saw operators, vibration exposure was evaluated according to the International Standard ISO 5349. Indices of daily vibration exposures and lifetime cumulative vibration dose were estimated for each chain saw operator. Results—Sensory nerve conduction in several segments of the median and radial nerves was significantly reduced in the chain-saw operators compared with that in the workers doing heavy manual work and the controls. The neurophysiological pattern more frequently observed in the chain-saw operators was a multifocal nerve conduction impairment to several neural segments with predominant involvement of sensory rather than motor fibres. Sensory nerve conduction velocities in the hands of chain-saw operators were inversely related to both daily and lifetime cumulative vibration exposures. In the vibration-exposed forestry workers, neither were sensori-motor complaints associated with vascular symptoms (finger whiteness) nor were electrophysiological data related to cold-induced changes in FSBP. Conclusions—Exposure to hand-transmitted vibration, in addition to ergonomic stress factors, can contribute to peripheral nerve disorders occurring in forestry workers who

operate chain saws. The findings of this study suggest the existence of an exposure–effect relationship for vibration-induced neuropathy. Different underlying mechanisms are likely to be involved in the pathogenesis of the neurological and vascular components of the hand-arm vibration syndrome.
Topics: Hand-transmitted vibration; Physiological effects (neurological and vascular).

NOTE: Copies of all papers in this section will be found in the Human Response to Vibration Literature Collection at the Institute of Sound and Vibration Research, University of Southampton. The papers may be used by persons visiting the Institute.

*Contributions to the Literature Collection are invited. They should be sent to Professor M. J. Griffin, Human Factors Research Unit, Institute of Sound and Vibration Research, University of Southampton, Southampton, SO*17 1*BJ, England.*