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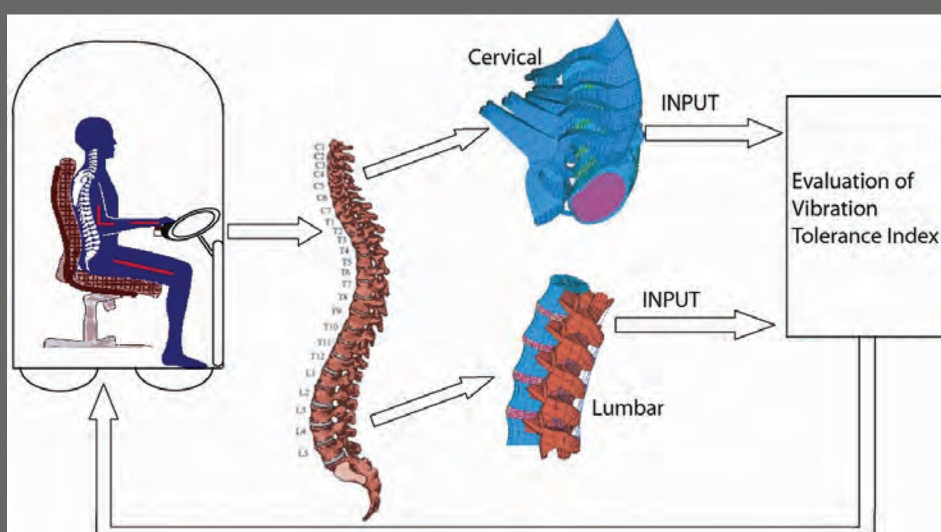


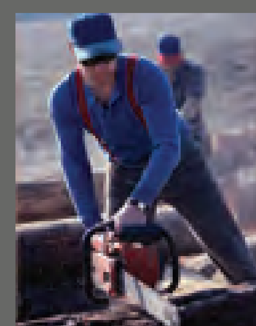

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# A COMPARISON OF WHOLE-BODY VIBRATION EXPOSURES BETWEEN LOW- AND HIGH-FLOOR BUSES

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## Introduction

Bus drivers represent a substantial segment of the U.S. transportation workforce. Research has shown an association between exposure to whole-body vibration (WBV) and low back disorders. The goal of this study was to compare and determine whether there were differences in vibration exposures between a low- and high-floor bus. High-floor buses require the rider to ascend steps (typically three) to reach the seating level. In low-floor buses, the rider steps directly on the bus and does not have to climb any steps. For accessibility and efficiency in passenger loading and unloading, low-floor buses are becoming the standard in larger metropolitan areas. Older high-floor buses predominate in many fleets, and in order to fully amortize the cost of the buses, cities are required to keep these buses in service for at least 15 years. As a result, both bus types will be in use as metropolitan companies transition from a predominantly high- to a low-floor bus fleet.

## Methods

The study comprised 25 participants: 15 drove a high-floor bus and 10 drove a low-floor bus. The high-floor bus (Gillig Corp., Hayward, CA), typical of somewhat older coach buses, was a 7-year-old, 12.2-m bus with a USSC ALX3 seat. The low-floor bus (New Flyer Industries, Inc., Winnipeg, Manitoba, Canada), typical of newer coach buses in a bus fleet, was a 4-year-old, 12.2-m bus equipped with a new USSC Q91 seat. All participants drove their respective bus for approximately 1 hr over a 65-km standardized test route. The buses were driven under identical load conditions with just the driver (no passengers) on board. The standardized test route included surface streets, freeways, and a small section of road containing eight 4-m speed humps. This route was chosen to represent different types of driving, including start-and-stop driving associated with surface streets, impulsive speed hump excursions, and continuous freeway travel.

The instrumentation developed for this study included a PDA-based portable WBV data acquisition system, which collected raw unweighted WBV data at 640 Hz, and the associated MATLAB and LabVIEW software to analyze WBV exposures, per ISO 2631-1 and 2631-5. Using the serial port on the PDA, global positioning system (GPS) data were also collected and integrated with the WBV exposure data to facilitate the identification of the location (road type) and speed of the bus. The preliminary analysis was focused on analyzing the Z-axis measurements of $A_w$, vibration dose value (VDV), crest factor, maximum continuous peak, and positive and negative raw weighted peaks. The crest factor was calculated by taking the maximum instantaneous weight peak value encountered during the route and dividing by the $A_w$ for the route. All parameter calculations were identical for the high- and low-floor buses. Data are presented as mean and standard error with significance accepted for p-values less than 0.05.

## Results

The GPS data indicated that there were no significant differences in bus speeds between the two bus conditions. Table 1 shows the preliminary results of the analysis of time-weighted average and peak data between the two bus types and between the bus seat and floor. When comparing the floor vibration levels between the buses, the magnitude and direction of the difference depended on the type of measure. Except for the average root-mean-square (rms) vibration exposure ($A_w$), all floor vibration measures were greater on the low-floor bus, with the impulsive measures (crest factor, maximum peak, and raw weighted peaks) twofold to fourfold higher. When comparing the seat vibration levels, except for the average rms vibration exposure ($A_w$) and crest factor, the opposite trend in seat vibration levels was observed. All seat vibration measures were lower on the low-floor bus despite the greater floor vibration levels.

**Table 1.—Mean and standard error Z-axis vibration measures by location and bus type (n = 10)**

| | Seat | | | Floor | | |
|---|---|---|---|---|---|---|
| | Low-floor (n = 10) | High-floor (n = 15) | p-value | Low-floor (n = 10) | High-floor (n = 15) | p-value |
| $A_w$ ($m/s^2$) | 0.40 *± 0.02* | 0.49 *± 0.01* | < 0.001 | 0.43 *± 0.01* | 0.46 *± 0.01* | 0.001 |
| VDV ($m/s^{1.75}$) | 9.54 *± 0.47* | 11.80 *± 0.30* | < 0.001 | 12.37 *± 0.40* | 10.54 *± 0.23* | < 0.001 |
| Crest factor | 12.45 *± 0.50* | 12.38 *± 0.67* | 0.93 | 23.73 *± 2.00* | 12.37 *± 0.53* | < 0.001 |
| Maximum peak ($m/s^2$) | 4.71 *± 0.24* | 5.95 *± 0.32* | 0.005 | 9.76 *± 0.76* | 5.53 *± 0.20* | < 0.001 |
| Raw (+) peak ($m/s^2$) | 8.48 *± 1.10* | 9.65 *± 0.47* | 0.28 | 55.31 *± 2.68* | 15.17 *± 0.60* | < 0.001 |
| Raw (–) peak ($m/s^2$) | –7.14 *± 0.54* | –8.89 *± 0.67* | 0.07 | –64.67 *± 5.03* | –16.00 *± 1.52* | < 0.001 |

## Discussion

There were significant differences in the floor-measured vibration between the buses, with twofold to fourfold higher impulsive vibration measures in the low-floor bus. The opposite trend was seen in the seat; lower vibration levels were measured from the seat in the low-floor bus. These differences could be due to differences in seat design and age. The high-floor bus had a 7-year-old seat, while the low-floor bus a new seat. However, what is evident from this study is that seats on low-floor buses need to be able to attenuate higher-magnitude impulsive exposures. The new seat used on the low-floor bus in this study demonstrated that it was effective in attenuating these higher-magnitude impulsive exposures. Additional work with new seats should be conducted on high-floor buses to determine if new seats have the same attenuating effect, and further analyses should be done to determine whether there are frequency differences in the vibrational exposures between the two bus types.

## References

ISO [1997]. Mechanical vibration and shock: evaluation of human exposure to whole-body vibration. Part 1: General requirements. Geneva, Switzerland: International Organization for Standardization. ISO 2631-1:1997.

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