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Correlation between weighted acceleration, vibration dose value and exposure time on whole body vibration comfort levels evaluation

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ABSTRACT

Every environment offers stimuli to subjects. Some of these stimuli can be harmful to the human health, like vibration, depending on the intensity and/or exposure duration, among other factors. Even if the vibration is not harmful, it may cause discomfort. The ISO2631-1 (1997) Standard says that two exposures are equivalent when they have the same vibration energy. For that, it uses the exposure duration and the weighted acceleration or Vibration Dose Values (VDV) to calculate the equivalence, being those terms a power of 2 or 4, respectively, in the equivalence formula. Despite that, Annex C of the Standard states that there is no conclusive evidence to support a time dependency of vibration on comfort, reporting that some studies uses the frequency-weighted rms acceleration to calculate the dose of vibration received during an expected daily exposure (called eVDV – for Estimated). It should be expected that the same vibration energy would cause equivalent effect (on health or comfort). In order to verify this hypothesis, two frequency weighted acceleration values, measured according to ISO2631-1 (1997, 2010), were adopted, considering four different exposure durations in a way to reach three pre-established eVDV. The same frequency was considered for all studied situations to easy the comparison. To say that the time, the exposure duration or the VDV by itself are important parameters on the vibration influence can be naive and that was not confirmed in this study. The conclusion is that these variables superimpose themselves mutually, having different influences according to the other parameters involved.

1. Introduction

There are a lot of harmful stimuli to the human health. Physical agents like noise, heat, vibration and radiation are examples of environment stressors that can change the body function. They can not only lead to individual organic, social and economic damages, but also increase the occupational risk of accidents (Horvath and Bedi, 1990).

The ISO 2631-1 standard (ISO2631-1, 1997) gives guidance on how to use the evaluation methods for human exposures to vibration. For that, frequency weightings and multiplying factors for each evaluation axis are applied, as the human response to vibration and its effect are known to be dependent on the vibration frequency, direction and studied effect (health, comfort or task). The ISO 2631-1 only gives guidance to vibration tolerance limits, since the frequency weightings have been based on frequency-dependence subjective responses found in experimental studies (Subashi et al., 2009). This comment is important since, the frequency weightings of the ISO standard have been questioned (Morioka and Griffin, 2008). There is also no precise definition of the vibration exposure safe limits. For that reason, the European Community defined safety values for a working journey of eight hours (2002/44/EC, 2002), which are now incorporated in the 2010 version of the ISO 2631-1 standard for health purposes (ISO2631-1, 1997).

Whole-body vibration (WBV) is an ordinary stimulus present in every means of transport, some buildings or even in working environments, like heavy duty machine driving or shop floor. The WBV damaging effects are caused by a complex force distribution as a result of the oscillatory movement of the body (ISO2631-1, 1997). The absorption of these forces and its effects on comfort, health or even performance of task will depend on different factors. Amplitude, frequency and exposure duration (Griffin, 1990; ISO2631-1, 1997), individual corporal structure, position on the vibrating surface, the adopted posture and other associated stimuli, such as noise and heat are some

Abbreviations: R.M.S, Root Mean Square; VDV, Vibration Dose Value ($m/s^{1.75}$); eVDV, Estimated Vibration Dose Value ($m/s^{1.75}$); WBV, Whole-Body Vibration

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Nomenclature

a_w	frequency-weighted R.M.S. acceleration
$a_w(t)$	weighted acceleration (translational or rotational) as a function of duration (in m/s^2 or rad/s^2, respectively)
T	exposure duration (in seconds)

examples of these factors (Griffin, 1990; Mansfield, 2004). Moreover, factors like the kind of activity performed by the individual, the expectation, the state of humor, the vibration perception and the discomfort sense can change the WBV effects and can always varies within the individual and within different situations on the same individual due to the inter and intra-subjectivity (Griffin, 1990; Mansfield, 2004).

Toward and Griffin (2009) published a study about the influence of backrest on the apparent mass of seated subjects. For that, they investigated different inclinations for both rigid, as well as different foam thickness backrests. Their conclusion was that the contact with backrest and its characteristics influence the vertical apparent mass of seated subjects and the backrest influence the transmission of vertical vibration through a supporting seat cushion. Despite that, due to the lack of instrumentation, it was not possible to evaluate the influence of backrest at the current study and that may be pointed out as a limitation of the present study.

There is also a great variety of claims related to physiological effects caused by WBV (Lings and Leboeuf-Yde, 2000; Waddell and Burton, 2001), like motion sickness, discomfort and severe physical damages, as well as, headache, dizziness, low back injuries, sleep disturbs, anxiety, hypertension, emotional stress, vision problems, attention deficit tinnitus, besides hearing problems.

Considering the exposure duration, the aim of the present work, serious injurious effects caused by WBV can be observed after a long exposure period (ISO2631-1, 1997). Then, the discomfort caused by a short period of WBV exposure and that precedes the most severe effects, has demanded particular attention of researchers interested in the occupational health and ergonomics (Duarte et al., 2002; Pennestri et al., 2005; Seidel, 1993).

The European Directive regarding the exposure of workers to vibration (2002/44/EC, 2002) establishes the minimum requirements for the workers' health and safety under WBV. The directive determines that the employers must measure the WBV exposure during the working journey. It establishes two different WBV limits to know, the Exposure Action Value (EAV) and the Exposure Limit Value (ELV). If the EAV is exceeded, preventive measures must be adopted to reduce the exposure intensity, duration and occurrence. On the other hand, the ELV should never be exceeded. The value set is dependent on the chosen parameter: weighted acceleration value or Vibration Dose Value (VDV) (ISO2631-1, 1997). Thus, the limits of EAV are set to 0.5 m/s^2 or 9.1 m/s$^{1.75}$ and the ELV to 1.15 m/s^2 or 21 m/s$^{1.75}$, respectively.

Comfort is a very subjective concept (Pennestri et al., 2005). The automotive industry deals with comfort research due to marketing reasons and uses a classification that distinguishes vibration, static, postural, acoustic, visual and tactile comforts. However, even in this context of marketing, researches about comfort are useful to indicate appropriate levels of vibration for human exposure. The ISO 2631-1 (ISO2631-1, 1997) indicates the same relationship for both health and comfort WBV equivalent levels, varying only the multiplying factors in each case and which levels are used. Such standard define how to evaluate WBV comfort in objective manner, considering the three most important exposure parameters: duration, amplitude and frequency (ISO2631-1, 1997; Pennestri et al., 2005). In order to control these parameters, researchers prefers experimental studies instead of *in situ* investigations (Griffin, 1990). In 1987, the British Standard BS-6841 suggested the most accurate assessment of vibration exposure, which is used until the present day (Griffin, 1990; Mansfield et al., 2000). This standard uses the Vibration Dose Value (VDV) to assess vibration exposure during a period of time. This dose value will be described in item 2.3.

The ISO2631-1 (ISO2631-1, 1997), in Annex B.3, states that two

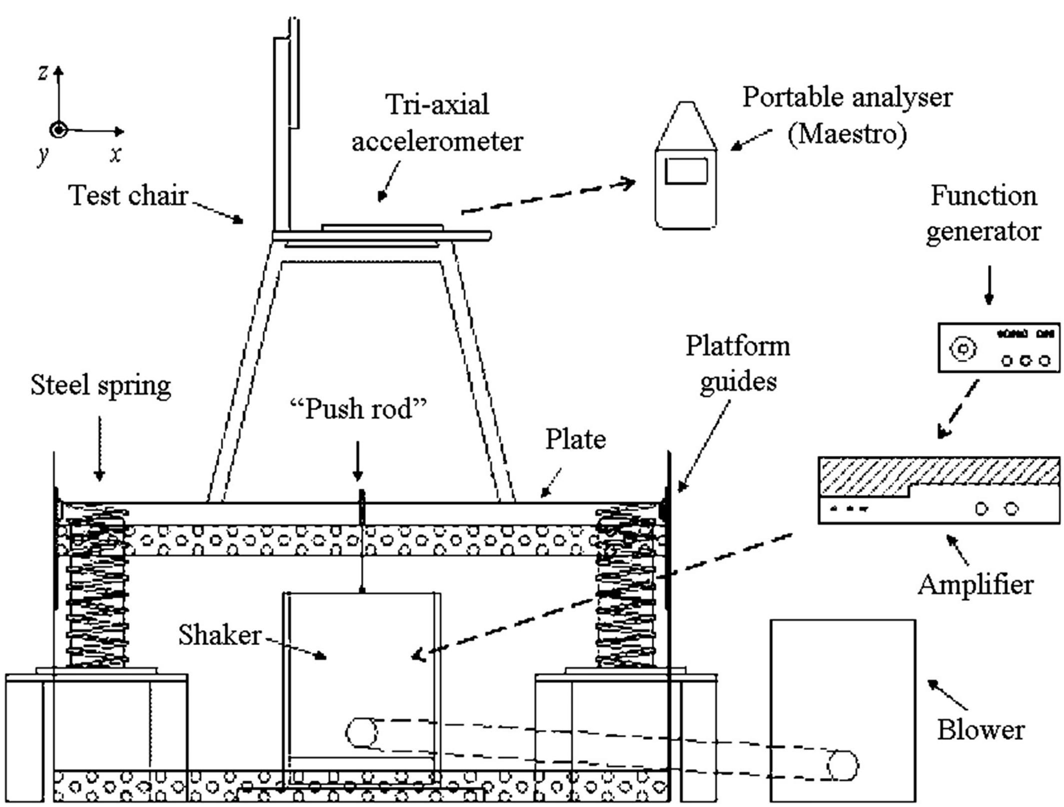

Fig. 1. Schematic drawing of the assembly.