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Comparative analysis of exposure limit values of vibrating hand-held tools

Mónica López-Alonso [a,1], Rosalía Pacheco-Torres [a,2], Mª Dolores Martínez-Aires [b,*], Javier Ordoñez-García [a,2]

[a] *Department of Construction & Project Engineering, University of Granada, E.T.S.I.C.C.P. C/Severo Ochoa s/n, 18071 Granada, Spain*
[b] *Department of Building Construction, University of Granada, E.T.S.I.E. C/Severo Ochoa s/n, 18071 Granada, Spain*

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A B S T R A C T

In the European Union, one of every four workers claims to be exposed to vibration for up to 2 h of his/her working day. The use of vibrating hand-held tools is the most common cause of vibration-related injury in workers. Of all sectors of professional activity, the construction industry has the highest number of workers affected by vibration. European Directive 2002/44/EC on the minimum health and safety requirements regarding worker exposure to risks from physical agents (e.g. vibration) limits exposure to vibration.

This study analysed the exposure level of construction workers to hand-arm vibration. For this research, vibration levels of the most common construction tools were compared, and the maximum time that each tool could be safely used was established. Finally, these limit values were compared to the tool vibration data provided by manufacturers. The results showed that for 42% of the tools studied, the daily exposure limit value was exceeded.

Relevance to industry: There was a significant divergence between the vibration limits in standards and the information provided by manufacturers.

1. Introduction

In the European Union, one of every four workers claims to be exposed to vibration for up to 2 h of his/her working day, in the hand-arm system or in the whole body (Office for Official Publications of the European Communities, 2008). According to the National Survey of Security and Health Management in Companies,[3] carried out by the National Institute for Occupational Safety and Health at Work[4] (INSHT, 2009), the risk of musculoskeletal problems related to posture, force, or repetitive movements at construction sites is 36%. This survey also underlined the social and economic impact caused by these disorders (Klussmann et al., 2010).

The use of hand-held vibrating tools is the most common cause of vibration-related injury in workers. Of all professional sectors, the construction industry has the highest number of workers affected by vibration (23.5% in the hand-arm and 12.9% in the whole body), followed by the industrial sector (16.6% in the hand-arm and 7.8% in the whole body) (INSHT, 2007).

The symptoms of exposure to hand-arm vibration can be classified as vascular, neurological, or musculoskeletal (Griffin and Bovenzi, 2002). All vascular symptoms can be classified under the heading of "Vibration White Finger", a phenomenon characterised by the whitening of the finger when exposed to low temperatures. The prevalence of vascular symptoms in workers using portable or hand-held vibratory tools can be as high as 70% or more, depending on the type and duration of exposure (Harada, 2002). The most common neurological disorders are numbness and tingling in the fingers. The musculoskeletal damage associated with hand-arm vibration manifests itself in the form of pain in the upper extremities (Griffin, 1998).

Other related symptoms include a continuous sensation of numbness (Laskar and Harada, 2005), loss of manual sensitivity and dexterity (Rui et al., 2008), demyelination (loss of nerve fibre) in the peripheral nerves of the hand (Kurozawa and Nasu, 2001), tendonitis, tenosynovitis (Griffin, 1998) and even advanced hearing loss (Masayuki et al., 1985). Recent studies also point to the appearance of Carpian tunnel syndrome (House et al., 2009).

* Corresponding author. Tel.: +34 958 24 62 97.
E-mail addresses: mlopeza@ugr.es (M. López-Alonso), rosapt@ugr.es (R. Pacheco-Torres), aires@ugr.es (MªD. Martínez-Aires), javiord@ugr.es (J. Ordoñez-García).
[1] Tel.: +34 958 241338.
[2] Tel.: +34 958 249438.
[3] In Spanish: *Encuesta Nacional de Gestión de la Seguridad y Salud en las Empresas (ENGE).*
[4] *Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT).*

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1.1. State of the art

The level of vibration transmission to the upper extremities depends on the magnitude, frequency, and direction of the vibration, the dynamic response of the hand (Griffin, 1990), and the worker's way of grasping the tool.

A physiological factor that interferes with the transmission of the vibration is the impedance or resistance to vibration. The main factors that influence impedance of the hand-arm system are: grip force (especially at frequencies of 30 Hz), push force, and direction (Kihlberg, 1995; Burström, 1997). According to Burström (1997), at frequencies lower than 30 Hz, the flexion or abduction of the hand or elbow also affects impedance. In addition, the relative position of the wrist-elbow also has an impact at certain frequencies. Therefore, at low frequencies (<30 Hz), impedance is greater when the arm is bent, and at a frequency higher than 70–80 Hz, impedance increases with the flexion of the elbow. Stronger grip force and push force mean an increase in impedance in both the resonance frequency and its magnitude (Besa et al., 2007).

Various authors (Sam and Kathirvel, 2009; Edwards and Holt, 2006) claim that the technique used is of utmost importance to the maximum levels of vibration received. When assessing technique, it is thus necessary to consider factors such as the following: grip force, induction force, handle type, and worker posture, and arm position (straight or flexed) relative to the tool (Alphin et al., 2011). Aldien et al. (2006) found that the vibration absorbed by a straight arm is greater than the vibration absorbed by a flexed arm. Other factors to bear in mind are tool material and design. In addition, Edwards and Holt (2007) highlight other crucial parameters such as the age of the machine and the shape of the handle.

As specified in Directive 2002/44/EC (2002), the greatest challenge is the reduction of the daily exposure limit value for vibration. Not surprisingly, this requires changes in work methods and equipment. The use of modern tools with low levels of vibration is one way to reduce the risk of exposure, but it is also necessary to decrease actual exposure time to vibration. In fact, according to Greenslade and Larsson (1997), controlling exposure time is the most effective prevention method.

Other methods include: (i) changing work procedures to avoid the use of certain machines with high vibration levels (HSE, 1997); (ii) hiring a qualified technician to study the situation; (iii) designing maintenance programmes for work equipment; (iv) using auxiliary equipment to reduce vibration risks; (v) wearing suitable clothes as a safeguard against cold and damp (Nelson and Brereton, 2005).

1.2. Objectives

The objective of this study was to identify the most common hand-held tools in construction work and determine their vibration levels, based on information provided by manufacturers. The results obtained were then compared with the limit values in the EU Directive 2002/44/EC to evaluate the validity of these vibration specifications from the manufacturers.

Once those tools with the highest levels of risk for occupational health were detected, their safe maximum exposure time was then determined. This time was regarded as the maximum time that a worker could use the tool without exceeding the vibration exposure level in the EU Directive. To do this, the vibration level of each tool was taken into account as well as the preventive measures that reduce the risk to worker health.

1.3. Legal framework

European Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (Directive 2002/44/EC, 2002), also known as the Physical Agents Directive, implements Council Directive of 12 June 1989 and formulates measures to improve safety and health at the workplace (Council Directive 89/391/EEC, 1989), This directive limits exposure to vibration by defining the daily exposure action value (see 2.2), as well as by specifying the employer's obligation to monitor health and safety risks arising from exposure to mechanical vibration (see 2.3).

The transposition of this directive to Spanish law is Royal Decree 1311/2005 of 4 November 2005. This law protects the health and safety of workers from risks arising or likely to arise from exposure to mechanical vibration[5] (Royal Decree 1311/2005, 2005).

1.3.1. Employer obligations

Employers are required to evaluate the level of exposure to vibration, but are only obliged to measure those vibration levels that are considered to be a risk in cases when this is considered "necessary".[6] The risk evaluation methods in the Directive include both a quantitative approximation (based on data regarding the probable magnitude of the vibration) and a qualitative approach (observation of specific work practices, conditions of use, and interactions with the workplace and equipment). During this risk evaluation process, employers can justify their reasons for not carrying out a more in-depth evaluation.

1.3.2. Manufacturer obligations

European Directive 2006/42/EC on Machinery (Directive 2006/42/EC, 2006) states that the design and manufacturing of machines must be carried out in such a way that the vibration transmitted to the operator is reduced to the lowest level possible. Technical advances and the availability of means of reducing vibrations at the source should also be taken into account. This Directive obliges the manufacturers of tools that produce hand-arm vibration to include the total vibration value to which the hand-arm system is subjected (measured in m/s^2) in the instructions, when this level exceeds 2.5 m/s^2 (Directive 2006/42/EC, 2006). The measurements should be taken at the site, as specified in harmonized standards (see ISO Standard 5349 (ISO 5349-1, 2001)). The measurement data should also include the operating conditions of the machine. Standard UNE-EN 12096 (AENOR, 1998) requires the manufacturer to declare the vibration level emitted by the machine, measured in m/s^2. Uncertainty values k should also be provided so that the test can be repeated.

2. Material and methods

This research study applied the calculation method outlined in the ISO 5349-1 (2001) (see 2.2). The exposure levels of the most commonly used tools were evaluated, based on data collected from the principal construction companies in the sector (see 2.1). To compare the data for various tool types, the term $A(1)$ was employed to refer to the exposure limit for 1 h. This made it

[5] In Spanish: *Real Decreto 1311/2005, de 4 de noviembre, sobre la protección de la salud y la seguridad de los trabajadores frente a los riesgos derivados o que puedan derivarse de la exposición a vibraciones mecánicas.*

[6] To be able to determine acceleration without having to measure it, employers must comply with each and every one of the following conditions: a) They must have evidence of the permitted emission levels of the machine. These can be the levels provided by the manufacturer or can be obtained by other means. b) The actual working conditions of the machine must be similar to those in place at the time when it complied with the legal emission levels. c) The machine must be in good condition and maintenance must be performed according to manufacturer recommendations. d) The tools and accessories used must be similar to those used when the acceleration levels were determined.