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Validity and inter-observer reliability of subjective hand-arm vibration assessments

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ABSTRACT

Exposure to mechanical vibrations at work (e.g., due to handling powered tools) is a potential occupational risk as it may cause upper extremity complaints. However, reliable and valid assessment methods for vibration exposure at work are lacking. Measuring hand-arm vibration objectively is often difficult and expensive, while often used information provided by manufacturers lacks detail. Therefore, a subjective hand-arm vibration assessment method was tested on validity and inter-observer reliability.

In an experimental protocol, sixteen tasks handling powered tools were executed by two workers. Hand-arm vibration was assessed subjectively by 16 observers according to the proposed subjective assessment method. As a gold standard reference, hand-arm vibration was measured objectively using a vibration measurement device. Weighted κ's were calculated to assess validity, intra-class-correlation coefficients (ICCs) were calculated to assess inter-observer reliability.

Inter-observer reliability of the subjective assessments depicting the agreement among observers can be expressed by an ICC of 0.708 (0.511–0.873). The validity of the subjective assessments as compared to the gold-standard reference can be expressed by a weighted κ of 0.535 (0.285–0.785). Besides, the percentage of exact agreement of the subjective assessment compared to the objective measurement was relatively low (i.e., 52% of all tasks). This study shows that subjectively assessed hand-arm vibrations are fairly reliable among observers and moderately valid. This assessment method is a first attempt to use subjective risk assessments of hand-arm vibration. Although, this assessment method can benefit from some future improvement, it can be of use in future studies and in field-based ergonomic assessments.

1. Introduction

Exposure to mechanical vibrations at the workplace, such as hand-transmitted vibrations, can arise in numerous labors (e.g., in construction or manufacturing industries), for example when manually handling powered tools. These hand-transmitted vibrations are associated with a variety of signs and symptoms including vascular and neurological disorders (Griffin and Bovenzi, 2002). More specifically, it has been shown in several reviews that hand-transmitted vibrations are associated with upper extremity complaints (Hagberg, 2002; Kittusamy and Buchholz, 2004; Punnett, 2004); for example, shoulder pain (van der Windt et al., 2000) and specific pathologies like tenosynovitis and epicondylitis (Palmer et al., 2007; Shiri and Viikari-Juntura, 2011). Although evidence is slightly inconsistent as there are also studies reporting weak evidence for the association of hand-arm vibration and upper-extremity complaints (da Costa and Vieira, 2010; Schweigert, 2002; van Rijn et al., 2010), it is generally accepted that hand-arm vibrations are an occupational risk.

As a result of these potential occupational hazards, in 2002, European directives were communicated providing workers' exposure limits for whole-body and hand-arm vibrations (2002/44/EC). These directives, that are based on health and safety requirements, specify the maximum intensity of vibrations a worker can be exposed to, considering the duration of this specific vibration. Assessment of hand-arm vibrations is therefore based on both the duration and the intensity of the exposure. This approach is

Abbreviations: HARM, hand-arm risk assessment method; ICC, Intra-class correlation coefficient.

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supported by several studies showing that vibration, in which the exposure is a multiplication of duration and intensity of the hand-arm vibration, is associated with upper extremity disorders (Bovenzi, 2012; Griffin, 2004; Sauni et al., 2009). Therefore, duration as well as intensity of vibration should be considered to quantify the potential risk of musculoskeletal disorders of hand-arm vibrations.

Objectively measuring hand-arm vibrations at work is laborious and challenging as highly specific and expensive equipment is needed. Occupational safety and health practitioners in general lack knowledge on how to perform these measurements (OSHA, 2008). Therefore, instead of objectively measuring hand-arm vibrations, assessments are often based on self-reports, guides, standardized technical reports and information provided by manufacturers. However, these sources can contain substantial errors. One reason might be that the actual exposure highly depends on the circumstances in which a task is executed, the tools that are used, the material that is processed and individual worker's characteristics. Another reason might be that such vibration assessments are often expressed in crude, qualitative metrics. Although validity of workers' self-reports of vibration of handheld powered tools were shown to be good to excellent (Stock et al., 2005), these estimates often systematically overestimate the actual vibration (Akesson et al., 2001; Palmer et al., 2000). Moreover, despite it has been shown that exposure to vibration should be expressed as a multiplication of the duration and the intensity of the vibration, only duration is addressed in the abovementioned studies. Therefore, reliable and valid assessment methods measuring vibration exposure in an easily applicable way at the workplace are scarce.

The hand-arm risk assessment method (HARM) was developed (Douwes and de Kraker, 2009, 2014). In this assessment method, which was developed for occupational safety and health practitioners, jobs are classified according to their risk of arm, neck and or shoulder symptoms. Among other factors, such as awkward postures and duration and frequency of force exertions, HARM takes the exposure to hand-arm vibrations into account. The HARM assessment method as a whole was tested elaborately and its predictive validity has been proven for arm, neck and shoulder pain (Douwes et al., 2014; Douwes and de Kraker, 2014). However, the quality of the subjective assessment of hand-arm vibrations which is part of the HARM assessment is largely unknown. During this particular subjective assessment of hand-arm vibrations, observers classify the intensity of the vibration into one of four vibration categories (Table 1), based on the European directives on the minimum health and safety requirements regarding vibration (2002/44/EC). Therefore a simple alternative was developed that is potentially more applicable than complicated and expensive objective measurements and more accurate than self-reports or the often used data provided by the manufacturers. The aim of the present study was to evaluate the inter-observer reliability and the concurrent validity of this subjectively assessed hand-arm vibrations (as used in HARM). In this study we hypothesize that our subjective assessment method provides a valid and reliable alternative for expensive objective assessments. Furthermore, we hypothesize that subjectively assessed vibration intensity is more accurate and reliable than (the often used) information provided by manufacturers as it is supposed that the intensity depends largely on the task performed. Eventually, we suspect that the subjective assessment method proposed here provides a suitable and easily applicable method that can be used in ergonomic practice.

Table 1
HARM vibration categories and corresponding description.

Category	Vibration intensity	Description of HARM category
1.	<2.5 m/s^2	Hardly any vibration sensible, or no vibrations visible to the observer and worker
2.	≤ 2.5–5 m/s^2	Vibrations not visible, but are sensible to the observer and worker (tingling feeling)
3.	≤ 5–10 m/s^2	Vibrations just visible to the lower arm/hand and sensible to the observer and worker
4.	≥ 10 m/s^2	Vibration of the hands, arms or shoulders can clearly be seen and felt by the observer and workers

2. Methods

2.1. Experimental protocol

In a lab setting, 16 tasks with powered tools were executed by two different workers, eight tasks by each worker. Therefore, two facility assistants (both male, 37 and 56 years of age respectively) with large knowledge and experience on handling tools were recruited to execute the tasks. A broad variation of tasks was selected (Table 3), in which tasks were ideally equally distributed among the four HARM vibration categories (Table 1). All tasks, consisting of the handling of several powered tools and processing several materials were executed in random order during which an objective as well as a subjective assessment of the hand-arm vibration was performed. These tasks were subjectively assessed by 16 observers, according to a mixed-design experimental protocol (Table 2). In this protocol, each of the 16 tasks were executed by one of the workers and were observed by four of the 16 observers leading to a total of 64 tasks that were observed. Observers were recruited from students and employees of the VU University, Faculty of Human Movement Sciences and TNO Healthy Living. These observers had substantial knowledge on human kinematics and ergonomic risk assessments. However, they did not have specific experience on performing assessments concerning hand-arm vibrations. Ten observers (62%) were female and the observers were on average 30.2 (12.1) years of age. All observers received written and verbal instructions on the subjective hand-arm vibration assessment. The instructions involved similar instructions to the instructions potential users of HARM receive. All participants to this study (workers and observers) signed a written consent prior to the measurements.

Hand-arm vibration was assessed subjectively using the vibration module within the HARM assessment, using the HARM vibration categories (Table 1). The vibration levels that should be distinguished were defined based on European directives (2002/44/EC) on health and safety requirements regarding vibration (0–2.5 m/s^2; 2.5–5 m/s^2, 5–10 m/s^2 and ≥ 10 m/s^2). The observers subjectively assessed each task by choosing one of these categories.

Table 2
Mixed design experimental protocol.

Task	Worker	Observer
1.	1	1–4
2.	1	1–4
3.	1	1–4
4.	1	1–4
5.	2	5–8
6.	2	5–8
7.	2	5–8
8.	2	5–8
9.	2	9–12
10.	2	9–12
11.	2	9–12
12.	2	9–12
13.	1	13–16
14.	1	13–16
15.	1	13–16
16.	1	13–16