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# Comparison of four task-based measurement indices with full-shift dosimetry in a complicated noise environment

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A B S T R A C T

This study was conducted to verify the agreement between four task-based measurement indices (TBMs) and full-shift dosimetry in a complicated noise environment. The study involved six production lines and 63 fixed jobs from an automobile wheel manufacturer. The subjects were simultaneously measured by the TBMs and a personal dosimeter, and 158 measurements were completed in total. There were two methods for measuring the level-at-task: average dosimetry noise level (ADL) and direct measure noise level (DML), and two methods for measuring time-at-task: worker diary (WD) and observation diary (OD). As for the differences, Pearson correlation coefficients, paired-samples t-tests, scatter and Bland–Altman plots were undertaken to assess the agreement between TBMs and the dosimeter. The results indicated that the TBMs agreed well with the personal dosimeter; the differences between them ranged from 0.16 to 3.07 dBA. The DML of level-at-task was less than the ADL result of 3.39 dBA and using the DML could cause a systematic error. The results showed that the TBMs from WD were as accurate as the TBMs from OD, and the WD recorded 88% of the task transitions of OD. Our research suggests that the TBMs, which uses ADL and OD, can be a reliable and more feasible as a cost effective strategy for assessing the full-shift noise exposures in practice. The study showed a high degree of agreement between TBM and dosimetry in fixed jobs and complicated noise environments. However it is not clear how well the agreement between TBM and dosimetry is in mobile jobs, and thus requires further studies to assess these environments.



## 1. Introduction

An occupational epidemiological study requires a measure of health outcomes and one or more potential explanatory variables (occupational or environmental exposure, etc.) for each subject. The ideal approach is to relate health outcomes with quantitative measurements of exposure for each of the subjects (Armstrong, 1998; Benke et al., 2000). Reliable and accurate measurements serve as the basis for its relevancy. It stands to reason that quantified personal measurement is the best approximation of personal real exposure (Pearce et al., 2004), and imprecise exposure assessment impedes determination of quantitative exposure-response relations and may result in false negative conclusions about the aetiological significance of occupational exposures (Svendsen et al., 2005). The exploration of dose–response relationships between occupational noise exposure and noise induced hearing loss also apply to the same rule.

Occupational noise exposure can be monitored directly by personal sampling or indirectly by area sampling (Atzeri and Cocco, 2004). Personal sampling is performed by using an integrating sound level meter, also known as noise dosimeter, worn by the subject while performing his/her work. For years, since the development of personal sampling technology, noise dosimeters have been used widespread for personal noise measuring. Before the use of personal sampling, area sampling was applied for exposure monitoring. When area sampling is used, measurements need to be made in all locations where a typical subject stays while performing his/her tasks, and the respective partial lengths of exposure

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need to be accurately recorded. The data collection aspect, which is similar to task-based exposure assessment modeling, was developed in the late 1970s as a noise control engineering modeling tool to aid in estimating the benefit of using these applications in tests for feasibility (Hager, 1998). When using dosimeters for large occupational noise measures, the measuring equipment and length of time are often expensive and long. This has led to a search for low-cost and convenient methods of monitoring.

With regards to earlier methodologies, numerous studies have reported the use of task-based exposure assessment strategies for noise (Hager, 1998; Neitzel et al., 1999; Kerr et al., 2002; Seixas et al., 2003; Virji et al., 2009; Li et al., 2011; Neitzel et al., 2013), ergonomic epidemiology (Mathiassen et al., 2003; Svendsen et al., 2005), dermal exposure (Kromhout et al., 2004), respiratory exposure (Goldberg et al., 1997; Susi et al., 2000; Beach et al., 2001; Fritschi et al., 2003) and others. Previous studies have revealed several advantages for task-based measurement (TBM), including more opportunities to identify high exposure tasks for targeted controls (Hager, 1998), more precise estimates of the mean exposures of occupational groups when the task levels and the task times are highly variable (Nicas and Spear, 1993a,b; Benke et al., 2000; Virji et al., 2009), and less expensive and more convenient for the measuring of large occupational groups (Li et al., 2012). Despite these strengths, the TBM is nevertheless limited in several ways; the most important aspect is its accuracy and also its feasibility. Virji et al., 2009 have reported that TBM work fairly well with the full-shift noise dosimeter, and Li et al., 2012 have suggested that the TBM are acceptably accurate with workers' dosimeters. However, Seixas (2003) and Reeb-Whitaker (2004) have reported only moderate agreement between the TBM and full-shift noise dosimeters among construction workers. Meanwhile, a number of challenges associated with its accuracy including a clear definition of the tasks, the measuring of the tasks' exposure level and the recording of the tasks' duration need to be resolved without delay.

In this study, we used four methods to build the TBM indices (TBMs) for the first time in a complicated noise environment, and tried to explore whether it could be a supplementary method for worker's noise exposure monitoring. We developed the study in several production lines of an automobile wheel manufacturer to validate the agreement between four TBMs and dosimetry for full-shift noise exposure, and to explore the possible influence factors of any disagreement.

## 2. Methods

### 2.1. Selection of subjects and tasks definition

The study was conducted at a wheel manufacturer in the city of Shiyan, Hubei province, China. The factory has seven workshops, 16 production lines of six categories, and more than 2000 workers. One typical production line was sampled from each category and there were six production lines sampled. Each line had 5-21 various jobs, and each job was measured 1–4 times. The subjects were simultaneously measured by the TBMs and a personal dosimeter for full-shift noise exposure.

Prior to noise measurement, we performed a pilot study and occupational hygiene investigation to verify the feasibility of the measurements, and identified the production line jobs and tasks. The tasks' names and their activities were defined by the researchers, the occupational hygienic staff, the managers of the factory and the experienced workers. Then the researchers trained the subjects in recording the tasks before the start of the study. The sampling was conducted in the routine days, so that the measurements would represent the average noise exposure level to ensure that the level-at-task was stable and repeatable.

### 2.2. Description of production lines

The six production lines were the punching and cutting line (PCL), the shield ring line (SRL), the rolling felloe and spoke line (RFSL), the shaping felloe and spoke line (SFSL), the assembling tire line (ATL) and the assembling tubeless tire line (ATTL). Descriptions of the lines are as follows: 1) The PCL involved cutting large steel into small plates for the follow-up production, and the main production processes included cutting, shot-blasting, punching and polishing. 2) The SRL produced the shield ring from the primal steel strips for the assembly line; its main task included cutting, air-powered regulating, notching and thermoforming. 3) The RFSL produced the wheel felloe from the small steel plates and combined felloe and spoke to form the wheel body. 4) The SFSL produced the wheel felloe from the small shaped steel plates and then combined the felloe and spoke to form the wheel body shell. 5) The ATL combined the wheel body, inner tube and cover tire into a whole wheel; its main production processes included combining, inflating and balance testing, etc. 6) The ATTL was very similar to the assembling tire line; it combined the wheel body and tubeless tire into a whole wheel.

With all of the production lines, exposure to non-continuous noise at a level of about 80–110 dBA was present. The tasks required for each job were relatively simple, each involving three aspects: the dominating activity, other activities inside the workshop and activities outside the workshop. Except for the different dominating activities, each job in the same production line had identical inside and outside workshop tasks.

### 2.3. Noise measuring methods

For full-shift noise measurement, the data was collected by a personal noise dosimeter which was carried in the subject's pocket during the whole work shift. Microphones of the dosimeter were covered by windscreens and attached to the workers' collars near their ears on the side of their dominant hand. Dosimeters were calibrated before and after each measurement. The inner memory recorded A-weighted equivalent continuous sound level ($L_{Aeq,2s}$) every 2-sec for the whole work shift. All data was loaded and stored in the computers after each measurement.

TBM were implemented and based on: (1) two different methods to measure the task noise exposure level ($L_{Aeq},t_i$) simultaneously; average dosimeter task level (ADL) and direct measure task level (DML); (2) two different methods to estimate the task noise exposure time ($T_i$) using the worker diary (WD) and the observer diary (OD). ADL was the arithmetic mean of three measurements of the dosimetry task level. Dosimetry task level was equivalent continuous A-weighted sound pressure level of 30 min ($L_{Aeq,30m}$) which was calculated from the tasks' 30 min dosimeter data. The data was selected from the full-shift dosimeter data. Based on the analysis of the pilot study, the task noise exposure level which was calculated from the tasks' 30 min dosimeter data was fairly representative of the real level-at-task (Fig. 1).

DML was equivalent continuous A-weighted sound pressure level of 10 min ($L_{Aeq,10m}$) which was directly measured by an integrating sound level meter handheld by the researchers on the same day as the dosimetry measurements. The measuring operation complied with the specifications of the ISO 1999:1990 (E) standard. The integrating sound level meter was handheld as close as possible to the worker's ear without compromising a safe operational area for the worker (about 1 m). The WD was completed by the workers, who were trained to record the tasks conducted and the amount of time spent at each task during the full-shift. OD was recorded by the researchers. Each of the researchers observed 3–5 workers simultaneously throughout the full-shift, and documented