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Pulse-video method for determining the workload and energy expenditure for assessing of work environment

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Abstract. Examining the humans work load and energy consumption allows us to identify the energy used for working postures and techniques and thereby create solutions how to make work technology and work environment better and altogether improve an employees work ability. There are several methods in which human energy consumption is determined by working postures, type of work and handling of loads, they all take account only the physical load factors ignoring mental or microclimate factors in the work environment. In recent times there are also used the mathematical models, in which the energy consumtion is determined on the basis of pulss frequency. The methods are complicated to realize them in the work situation because they do not allow to determine the dynamics of the work load in the work process. The aim of this research was to develop a method that enables to use a computer to determine and analyse the work process on screen at real time and that shows the employee's heart rate, work load and energy consumption momentary load values as well as their dynamics. The method is based on continuous measuring the employees pulse rate in the working process without disturbing him and at the same time also filming work process to make a video to demonstrate the results. We introduce the methodology how to measure an employees pulse rate, work load and energy consumption dynamics to make a compiled video. There are shown the fragments of research results about a farmer's and glassblower's work.

Key words: physical work, workload, energy expenditure, pulse-video, pigfarmer, glassblower.

INTRODUCTION

Human physical activity has a significant impact on health. It is important to investigate energy expenditure of employees because it can help detect unhealthy working postures and to motivate and steer toward a healthier work technologies. Improper work postures or work technologies can lead to excessive gravity of the work, which would result in the bone and musculoskeletal disorders, thereby reducing work performance among employees (Priya et al., 2010). It is important to examine the energy expenditure in the field of occupational physiology and health, because it provides useful information on the work of physiological load and helps to determine the energy needs of the employee (Anjos et al., 2007).

Usually for measuring the physical load and energy expenditure it is used oxygen consumption (VO2). However, under field conditions it is a cumbersome method for measuring oxygen consumption and therefore it is taken to propose other solutions (Smolander et al., 2007). There is also used the ISO 8996-2004, standard for the assessment of person's energy consumption, which has been shown in four methods for

evaluating the metabolic rate. At level one there are mentioned two assessments: metabolic rate by occupation and the classification of metabolic rate by categories. The second assessment is based on the estimation of metabolic rate by task requirements, influence of the length of rest periods and work periods, metabolic rate for a work cycle and metabolic rate for typical activities. The third assessment is based on analysis like the estimation of metabolic rate using heart rate and the relationship between heart rate and metabolic rate. The fourth, expert level, the determination of metabolic rate measured by oxygen consumption, using double-labeled water method, which allows to characterize the metabolic rate of a mean value over a longer period of time (1–2 weeks) and direct calorimetry method. Since the heart rate and the metabolic rate are in linear relationship the third method is easier than the other methods. Heart rate is easier to measure than oxygen consumption (ISO 8996, 2004).

For the employee energetic load determination there are used more variety of methods such as Ovako Working posture Assessment System (OWAS) – which is designed for heavy work to assess and take into account the person's working positions (84 indicators), ERGOLOG – employee is tested in the workplace, VIRA – takes into account a person seated posture and movement and it is captured on video, ARBAN – takes into account the position and the movable loads of the employee while standing or walking (Tuure, 1991; 1995), Hettinger method – for measuring the energy expenditure there is used generalized tables (Hettinger et al., 1989).

The described methods take into account only the physical load of the body but does not reflect the mental and the surrounding work environment (air temperature, humidity, noise, lighting, etc.) load factors, equipment design, workflow, etc. The used methods usually do not allow to determine the workload of the working human.

Because the heart rate response is very sensitive to the work environment changes, the heart rate and energy consumption or energy expenditure are in linear relationship (Andersen et al., 1978). To analyze and evaluate the work processes and work technology the EMÜ department of Husbandry Engineering and Ergonomics developed a method (Reppo & Käämer, 1998; Reppo et al., 1999; Reppo & Lindsaar, 2001; Mikson & Reppo, 2004; Mikson et al., 2005; Kuzmin, 2014; Nautras, 2015) where the work rate of the employee and energy expenditure in the work process is determined by the person's heart rate continuous measurement. This method is easier and less disruptive to the employee but the process requires tense monitoring of the work methods used by the employee for later to show the most interesting work method with the right pulse value.

The aim was to develop a method (pulse-video method) which would allow to use the employee measured heart rate and record the work process for later to be displayed on a computer screen in sync with the employee work process and his measured heart rate, workload and energy expenditure.

MATERIALS AND METHODS

The farmer’s and glassblower’s work load and energy expenditure have been demonstrated by pulse-video method. The pig farmer, 49 years old female with work experience of 5 years. The main tasks of the pig farmer are feeding and caring for animals, but also maintaining farm facilities (water pipes, hoses, fences and animal selters). When the video was taken, he was feeding the pigs. The glassblower, 31 years

old female with work experience of 7 years. A glass blower is responsible for designing, producing, decorating and finishing pieces of glass including giftware, exhibition pieces, tableware ect. Glass blowing technique involves handling molten glass, as well as a variety of tools, metals, and dyes for decoration and scientific notation. The main task of the glassblower, when the video was taken was making of glass jugs.

The pulse-video method takes into consideration both the physical, psychological risk factors and the surrounding environment to measure total impact to human energy expenditure. For determing the workload it is used Brouha and Nygard composed classification by the heart rate, which has been approved by the World Health Organization (WHO) (Tuure, 1991; 1995). The workload is classified by heart rate as shown: light (L) when the heart rate is less than 100 bpm, moderate (M) 100...124 bpm, heavy (H) 125...150 bpm and very heavy (VH) when more than 150 bpm. The energy expenditure is determined by the workload, sex and age of the employee (Andersen et al., 1978, Tuure, 1991; 1995).

The pulse-video method is based on continuous measurement of the employees pulse using the heart rate monitoring device (Suunto t6 measurement kit) at work and at the same time also filming the workprocess. Later the video is processed and based on the data of heart rate, the workload and energy expenditure are calculated (Fig. 1).

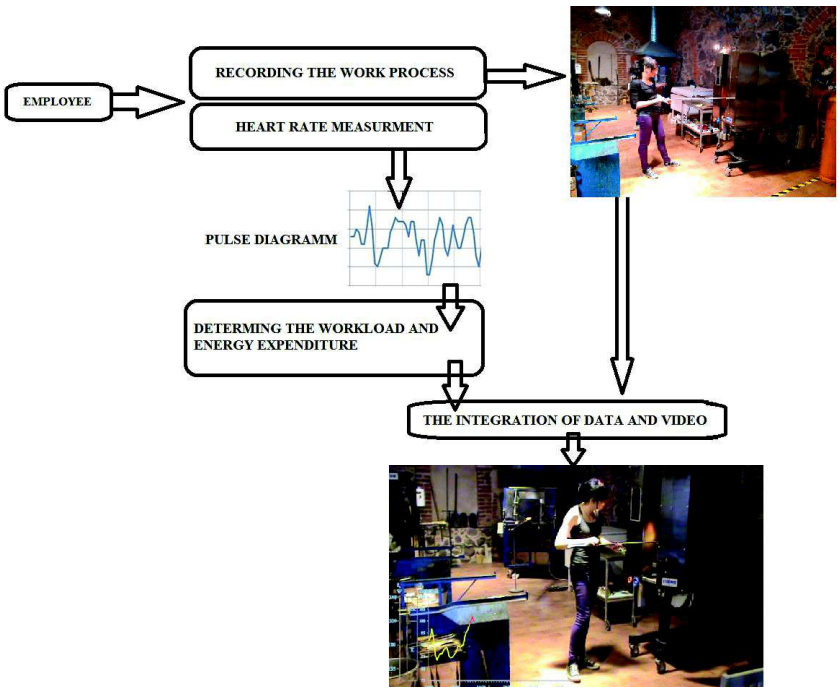

Figure 1. The realization of pulse-video method block diagram.

The data processing program MS Excel is used for the processing of heart rate data and creating a pulse diagram. For the integration of video and data there is used different programms like: Adobe Flash 8 Professional (Kuzmin, 2014), Photoshop and Adobe Premiere Pro (Nautras, 2015).

ESULTS AND DISCUSSION

The pulse diagram is supplemented through data interpolation with workload and energy expenditure on the additional scales (Fig. 2) which allows to monitor the dynamics of heart rate, workload and energy expenditure during the work process.

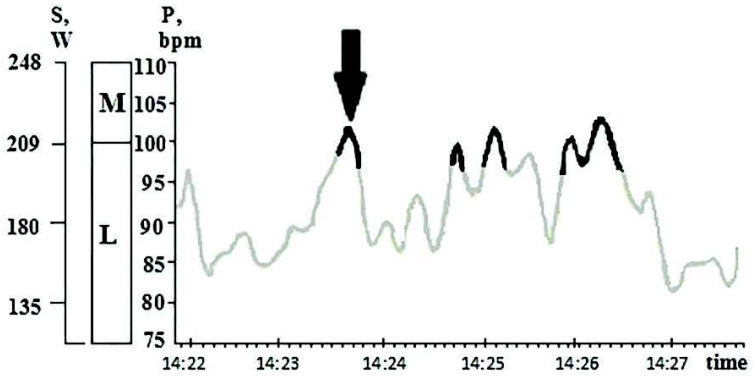

Figure 2. The glassblowers pulse diagram with additional scales of workload and energy expenditure: P – heart rate; L – light workload, M – moderate workload; S – energy expenditure.

Pulse-video method has been used for studing the pig farmer food distribution. The pulse-video is available on internet: https://goo.gl/zn3LG1. Fig. 3 presents a fragment from the pig farmer's pulse-video.

Figure 3. The fragment of pig farmer's pulse-video with additional time scales of workload and energy expenditure: S – energy expenditure (W); H – heavy workload, M – moderate workload; P – heart rate (bpm) (J. Kuzmin, 2009).

On Fig. 3 there is shown a fragment of the pig farmers pulse-video. The arrow indicates the current heart rate of the pig farmer which corresponds to 135 bpm (beats per minute), workload is heavy, and the energy expenditure is 350 W.

Fig. 4 shows a fragment about glassblowers pulse-video, where the glassblower is displayed on heating the glass mass at the furnace. Heart rate, workload and energy expenditure were measured during the exact time (see diagram in the left corner belov the figure), as displayed in Fig. 2 (indicated by the black arrow). It can be seen that the workload is moderate, because the heart rate was above 100 bpm (beats per minute) and the energy expenditure is 210 W.

Figure 4. The fragment of glassblower's pulse-video on heating of glassware (Nautras, 2015).

In spite of there are several methods in which human energy consumption is determined by working postures, type of work and handling of loads, they all take account only the physical load factors ignoring mental or microclimate factors in the work environment and more often using tables for measuring the work load (Tuure, 1991) and energy expenditure (Hettinger et al., 1989). Smolander and co-authors (2008) developed heart rate variability-based method (Firstbeat PRO heartbeat analysis software) for the estimation of oxygen consumption without individual calibration. There are methods like SYBAR which uses video but it is used for muscles and joints load analysis (Harlaar et al., 2000). The VIRA is another method that uses video, taking into account a person's posture and movement, but not work load and energy expenditure synchronously with the working process. Thereat, heart rate also can increase at low activity levels with high mental-strain of precision work (heating of glass detail) and additional thermal stress (Wilson & Crandall, 2011). The pulse-video method takes into account not only physical workload and energy expenditure, but indirectly demonstrates also mental and microclimate factors in the work environment, synchronously seen on a video. The glassblower's pulse-video is available online at: https://goo.gl/Z2uGcp.

CONCLUSIONS

Since the heart rate and the person's energy expenditure or energy load are in a linear relationship the workload and energy expenditure was determined by the continuous measurement of heart rate. The developed pulse-video method allows to follow the heart rate dynamics during the workprocess and later display them on a computer screen. It is possible to measure synchronously the work process and heart rate, workload and energy expenditure. The method is easy usable and less disruptive to employee in the work process.

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