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Evaluation of safety and arduousness of work conditions of feller with use of modern measurement methods

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Abstract: *Evaluation of safety and arduousness of work conditions of feller with use of modern measurement methods*. An analysis of issues relating to the subject of widely understood science of ergonomics is shown. Considerations of the authors concentrate on the assessment of arduousness of work of a worker in the workplace of a feller with special consideration of modern measurement methods implementation. The article also aims at establishing whether Body Media Sense Wear device and POLAR V800 with Polar Flow software are useful in monitoring of physical activity parameters of wood industry workers while diagnosing strain of their work.

Keywords: ergonomic, safety, energy expenditure

INTRODUCTION

In modern management of production processes, undoubtedly the most important place is occupied by a man, fulfilling the function of a worker, often a manual worker.

Every kind of work requires, first of all, adequate distribution of physical and mental forces appropriate for the work and its conditions. Strain on every organism is possible only in some limits. Prolonged, one-sided or excessive strain on an organism always results in disadvantageous influence on the organism.

Ergonomic aspects of design of defined organisational solutions concentrate on identification and implementation of elements, factors and solutions, the aim of which is complex adjustment of a work to a man. The complexity is understood as assuring the highest level quality of ergonomic work, taking into consideration all possible technical-organizational factors and material factors of the work environment existing in the workplace. But first of all as abilities, constraints and needs of a worker (Górska 2015).

One of the methods of measurement of work intensity can be, discussed in the farther part of the article, estimation of energy expenditure and change of chosen physiological parameters influenced by physical activity. The choice of an appropriate method of energy expenditure measurement is strictly dependant on the kind of activity, which is related to the kind of work.

Optimal assessment of the strain put on an organism during work is a very complex task and requires specialistic knowledge from among others work physiology and ergonomics as well as the ability of balanced final assessment. Wrong assumption of energy values can influence measurement error in the range of 30 % thus energy expenditure assessment can be disadvantageous for an examined person (Hławiczka and Ścieszka 2003).

The aim of the article is to present contemporary methods of assessment of physical strain of work on the basis of a wood industry worker – a feller. The main aim of the work was realised on the basis of desk research and determination and assessment of energy expenditure in the process of manual work, by modern methods of estimation, to which undoubtedly belong methods of energy expenditure measurement using heart rate monitoring and accelerometer, during feller's work.

A MAN-WORK SYSTEM

A man-work system arises when a man operates a machine, but also in other cases, for example when a man uses tools or when the work occurs without the aforementioned tools. A man-work system can be considered in all conditions of work of a man, only the second element of the system is defined in a different way. It should be noted that the term of a man-work system was acquired by ergonomics from psychology of work (Olszewski 1997). The term of a man-work system, called also an ergonomic system, is currently one of the basic terms of ergonomics. Owing to its use, it is possible to symbolically show every workplace. All elements of the system (man-work/machine) have symbolic character, because the term of a man can relate to both an individual (single worker) and to a group of people. A similar situation occurs in the second element of the system – work. It can be a tool, a workplace, a whole production line or a single device. Interaction of these elements impacts on some processes permanently existing in the system. Both elements act in determined conditions of external environment, and the environment has a determined influence on a man and work being elements of the system. There is also an inverse action, because elements of the system influence the environment both the closer and the farther one. Regarding the above also the term of a man-machine-environment system can be encountered. A man-work system can be considered in the category of system – ambiguous, relating to a set of rules of action, sometimes ways of organisation or arrangement or subordination of elements forming one unit (https://mfiles.pl).

PHYSIOLOGICAL PROCESSES OCCURRING IN THE PROCESS OF PHYSICAL WORK

Work physiology is a branch of science, which aims at determination and cognition of laws that direct physical and psychic activity of a man in different conditions of the process of work. Work physiology also deals with research on functional state of the human organism during the process of work and justification of organizational changes of technological processes, which contribute to the ability to farther carry out physical work in a workplace.

Results of research into work physiology largely help in working out norms, implementation of which contributes to increase in work efficiency and decrease in energy expenditure of work as well as preservation of optimal conditions for internal organs function.

Each living organism shows a common feature which is metabolism. Metabolism is a process consisting of two different processes:

- catabolism, which involves dissimilation, which is reduction the amount of energy in an organism
- anabolism, which involves assimilation, which is gathering of energy in an organism.

Physical work carried out by a worker constitutes one of the most important factors increasing the total amount of energy utilized by the worker's organism. It causes the fact, that during maximal physical effort metabolic rate in muscles increases over one hundredfold in comparison with the state when the worker is at rest. Thus it can be assumed that a change in metabolism meaning a transformation of matter and energy in a time unit can occur under influence of the following (http://ftp.pwsz.glogow.pl):

- physical work of different degree of strain,
- intellectual work and emotional states,
- changes in temperature of the human body,
- changes in temperature of the environment,
- increase in some hormones' blood concentration(for example excess of thyroxin),
- digestion and absorption of food.

ENERGY EXPENDITURE IN THE PROCESS OF PHYSICAL WORK

Energy expenditure from ergonomic point of view is essential in assessment of intensity of work in a workplace. Measurement of appropriate physiological parameters and their juxtaposition can be helpful in good allocation of work and workers in a workplace. Physiological parameters used for energy expenditure measurement of a production worker can be for example pulse rate, the amount of air that flows through the lungs. Energy expenditure is a basic parameter of the amount of energy used by a worker during received work.

Energy expenditure in a simple approach is the amount of energy that is used by a physical worker during an activity or work. Most often it is the measure of physical strain put on by dynamic physical work (https://www.dbc.wroc.pl). Energy expenditure is also used to determine intensity of work as an energetic criterion. The determined value of energy expenditure of a worker during a shift is used to assess intensity of the work they perform (tab. 1) – it is the amount of kilocalories necessary to perform the work. Energy expenditure is then expressed in effective kilojoules or net kilojoules, which is calculated by subtracting them from the total amount of used gross kilojoules, which express the value of basic metabolic rate (http://ergonomia.ioz.pwr.wroc.pl).

Table 1. Degree of physical work intensity in relation to energy expenditure during 8-hour shift (http://activebhp.pl).

Degree of intensity of physical work	Energy expenditure during 8-hour shift			
	Men		Women	
	Kilocalories [kcal]	Kilojoules [kJ]	Kilocalories [kcal]	Kilojoules [kJ]
Very low	Do 300	Do 1257	Do 200	Do 838
Low	301 – 800	1258 – 3352	201 – 700	839 – 2933
Medium	801 – 1500	3353 – 6285	701 – 1000	2934 – 4190
High	1501 – 2000	6286 – 8380	1001 – 1200	4191 – 5028
Very high	Over 2000	Over 8380	Over 1200	Over 5028

METHODS OF PHYSICAL WORK MONITORING IN PRODUCTION WORKPLACES

Until recently the most often applied methods of monitoring and measurement of physical activity were survey methods. An example of a standardised questionnaire is International Physical Activity Questionnaire (IPAQ) assessing all forms of physical activity, which was performed by a worker in last seven days. It is worth paying attention that such methods, mainly because of excess subjectivism, are more and more often replaced by more modern, more precise methods of physical activity monitoring in a production workplace.

The methods that use devices commonly called move detectors, acting on the basis of accelerometer, are among the most modern ones. One of these devices is pedometer – a small device which counts the number of steps, the distance travelled and the number of calories burnt. It is usually placed on a belt on the waist, fixing it as much as possible. Accelerometers are more precise move detectors. A device acting in this way is ActiGraph(model GT1M), which as the mentioned before pedometer is worn on the waist in order to obtain maximally reliable results.

Another method of physical activity measurement in a workplace is Sport Tester device, which records number of heart beats per minute. The device consists of a detector worn on a belt on the chest and a receiver in the form of a watch showing the pulse measurements. Depending on the model and the level of advancement, the device allows to program and control different kinds of physical activity.

METHODS OF ASSESSMENT OF ENERGY EXPENDITURE AND PHYSICAL STRAIN IN THE PROCESS OF WORK

Methods of assessment of energy expenditure and physical strain, which are applied in work physiology, are mainly associated with measurement of occurring changes, their dynamics and different parameters of the human organism during work. They are the following:

- earlier defined and described energy expenditure – including assessment of its value,
- examination of changes in the muscular system – analysis of muscles' fatigue, performed for example with dynamometer or ergograph or record of muscles' physiological currents – performing an electromyogram,
- observation and examination of the respiratory system – relying mainly on measurement of dynamics of respiratory parameters such as breath frequency, increase in minute respiration of the lungs or oxygen use,
- assessment of changes occurring in the central nervous system,
- analysis of the circulatory system – relying on observation and measurement of changes in hemodynamic parameters such as stroke volume, blood pressure or increase in heart rate.

CHARACTERISTICS OF WORK AND PHYSICAL STRAIN OF A WORKER IN A COMPANY OF WOOD PROCESSING IN THE WORKPLACE OF A FELLER

The workplace of a feller is closely related to obtaining wood in different age classes. The basic tool in works connected to processing wood resources into useful assortments and cutting trees is a petrol chainsaw. An accessory tool associated with sanitary cuts is a petrol saw with a cutting appliance on a boom.

The work of a feller with cutting trees and processing the obtained wood resource belongs to very dangerous jobs with very high occupational risk. Following rules and safety conditions requires the feller to prepare a chainsaw according to the producer's instruction, everyday inspection of cutting machinery and minor repairs if necessary. A feller apart from cutting trees in cuts and pre-cuts, cuts trees in order to make logging trails and technological trails depending on the used technological process (Tomczak 2012). The work of a feller is also related to loading wood assortments onto means of transport, which is a very tough work, and to tiding cutting surfaces after completed order. All kinds of work done by a feller must be planned in detail and organised in terms of technical protection and choice of work technique for a specified task, beginning with preparing an offer and attending an auction for performing forestry works. A worker in the feller workplace is usually obliged to strictly cooperate with representatives of a forestry superintendence, in particular with a forester in the area of a forestry, for which they fulfil an order.

It is difficult to give all elements of a feller equipment, because they use tools adequate to an order, largely specialized for a character of work. Elements of a feller's equipment are among others hooks for wood, hooks for rotating wood, a small universal hatchet , hooks for moving wood, autotightening forceps, a lever for moving logs, a hammer for splitting, an aluminium wedge, an aluminium curved wedge, a hand rotator, an aluminium rotator, a Swiss sickle, an axe for splitting, one-handed sickle, pruning scissors, a hatchet, telescope boom, branch saw, telescope saw, universal scissors for cutting branches, accessory measuring tools like diameter measure, measuring tape, usually metal, pliers for repairing measuring tapes or sharpeners of different type and size.

Assessment of energy expenditure with a POLAR V800 device and Polar Flow software (fig 1,2,3).

First of the methods used is a method of measurement of energy expenditure with a Polar V800 device and export of the obtained results with Polar Flow software. After studying the characteristics of a POLAR V800 device and Polar Flow software and its functions, measurement of energy expenditure with the device began. The measurement took place on 14th March 2019 in windy, moisture conditions, with large cloud cover, at the temperature of 4 to 7 Celsius degrees from 8:00 to 12:00 in the workplace of a feller in a forest area near the village of Korbielów. Below, obtained results in the form of diagrams generated with Polar Flop software are presented. Before starting the examination, necessary data relating to the diagnosed person were introduced into the Polar V800 device, which included:

- -date of birth, on the basis of which the age of the diagnosed person was assessed (24 years),
- -weight of the diagnosed person (70 kg),
- -height of the diagnosed person (175 cm),
- -maximal heart rate at the level of 196 bpm.

The examination was performed three times for an hour each time.

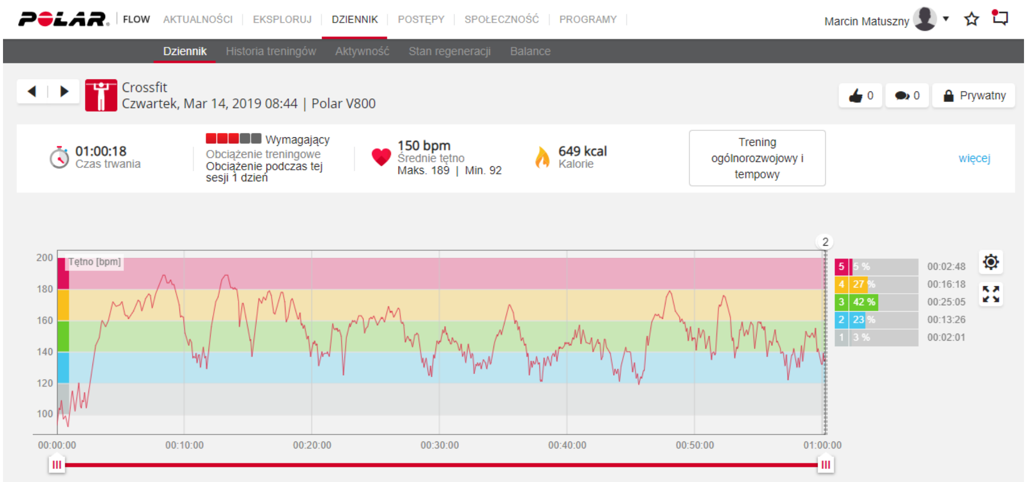

Figure 1. Research results – graph of the heart rate as a function of the time generated with Polar Flow software - the first measurement.

The graph above (Fig. 1) shows the beginning of a feller's work. The graph depicts particular activities comprising technical-organizational preparation.

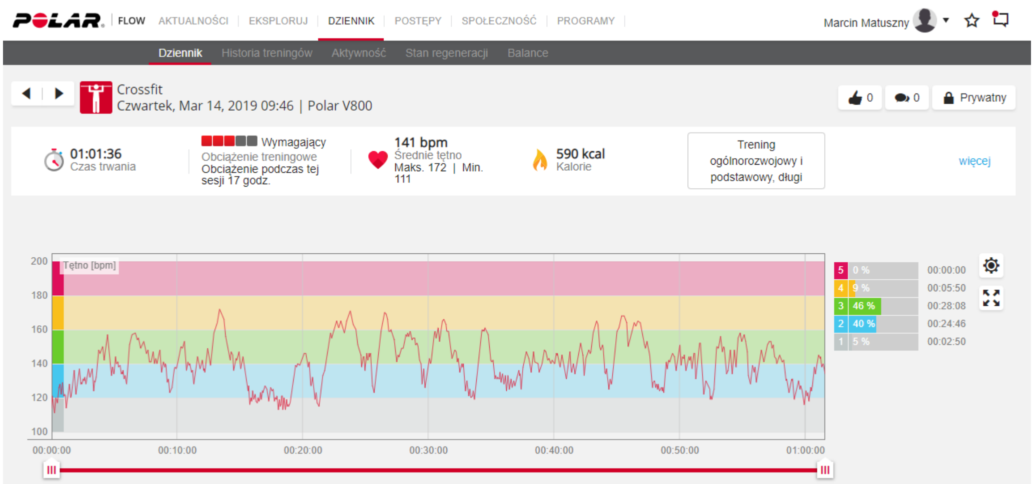

Figure 2. Research results – graph of the heart rate as a function of the time generated with Polar Flow software - the second measurement.

The graph above (Fig. 2) shows the next measurement, which was started with a change of the place of work of a few dozens of meters, moving the equipment necessary for work. Next a decrease in pulse rate occurred, which was related to change in the body position from standing to squatting, where the diagnosed person was refuelling a chainsaw and preparing it to farther work of cutting trees.

Whereas for the last 10 minutes of the measurement the diagnosed person was walking without a hurry, slightly tidying the place of cutting and preparing the place for farther work (Fig. 3). During this measurement energy expenditure of the diagnosed person was 590 kcal.

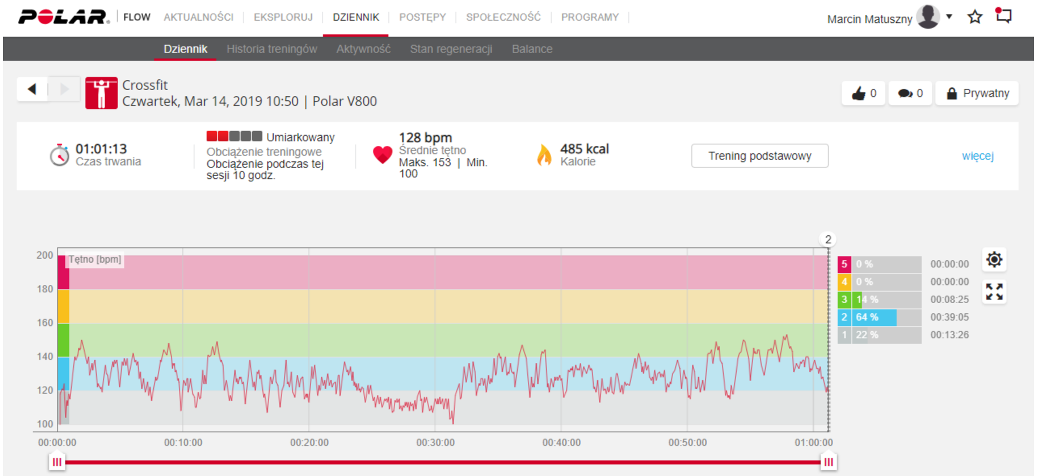

Figure 3. Research results – graph of the heart rate as a function of the time generated with Polar Flow software - the third measurement.

The last measurement include first 25 minutes of performing the process of work of cutting branches of lying trees, then (approximately 25 minutes in the graph), where decrease in heart rate occurred, utilization of the lying branches with a specialistic machine. After completing this activity the diagnosed person returned to work with a chainsaw being in standing position with slightly leaning body, performing work of medium degree of intensity according to the authors.

During the last measurement made by a Polar V800 device energy expenditure of the diagnosed person was equal 485 kcal.

1.Assessment of energy expenditure with the use of a BodyMedia System device and Sense Wear Software 7.0 software.

In order to complement the research and identify essential physiological parameters, it was decided to use also a BodyMedia System device with Sense Wear Software 7.0 software, available in the laboratory of Ergonomics and Protection of University of Bielsko-Biała (laboratorium Ergonomii i Ochrony Pracy Akademii Techniczno- Humanistycznej w Bielsku-Białej). Measurement with the use of the device mentioned above was conducted on 17.03.2019 in sunny conditions with slight wind blows, from 12:00 to 15:00. The temperature oscillated between 14 and 17 Celsius degrees, whereas the place of the measurement was a forest area near the village of Korbielów.

Obtained results in the form of a report generated with dedicated software are presented below (Fig. 4, 5).

Figure 4. Report generated with Sense Wear Software 7.0 – the first page.

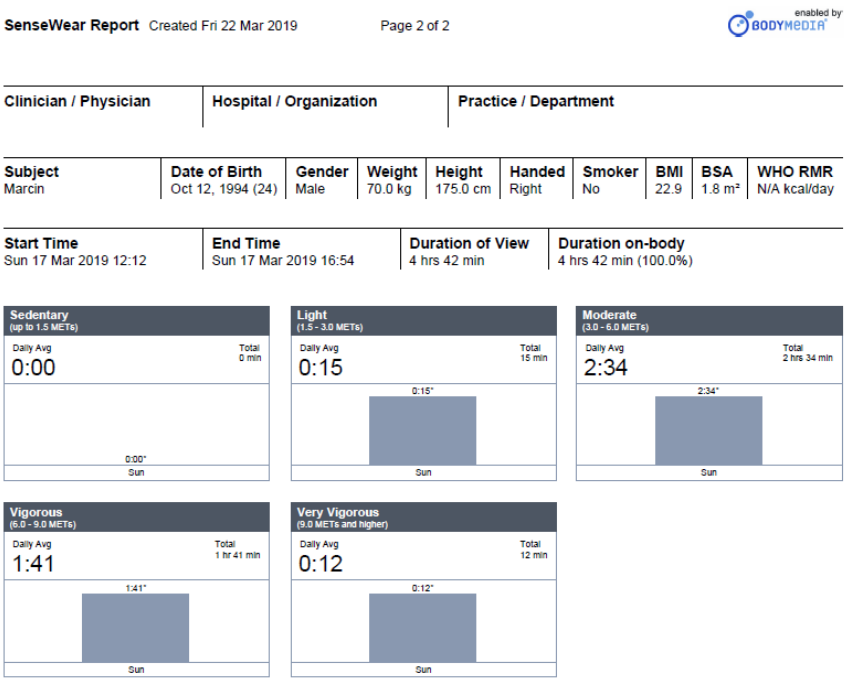

Figure 5. Report generated with Sense Wear Software 7.0 – the second page.

From the report generated above many parameters essential for the measurement of arduousness of a feller's work can be read. Among others the data of the examined person, their age, height or weight, moreover the report shown above takes into account that the diagnosed person is right-handed and non-smoking. Furthermore the software allows to generate BMI and BSA indexes. Next it can be read that the practical examination with BodyMedia belt began 17 March 2019 exactly at 12:12 and finished at 16:54, lasting without break (all the time the belt was placed on the hand of the examined person)for less then 5 hours (4 hours 42 minutes).

Analysing farther data from the report it can be read, that during the examination energy expenditure of a worker working in the workplace of a feller was equal 8031 kJ, which indicates that they were performing very intensive work. Besides energy expenditure it can be also read from the generated report how many steps the diagnosed person made during the work (9795 steps) and thus the distance made by the worker can be calculated, in this examination it was near 15 kilometres (14,9 km). In the next part of the report energy expenditure during the process of work expressed as a metabolic equivalent MET is shown. The author of the article reminds the 1 MET is equal oxygen intake at rest of ~ 3,5 ml * kg-1 * min-1. By means of the value of this metabolic equivalent, intensity of the physical activity during work can be determined, which is shown as a multiplication of 1 MET. 1 MET in simplification determines utilization of l kilocalorie by 1 kilogram of the body weight in 1 hour at rest, thus multiplication of MET shows how many times more energy is used during physical activity in comparison with the energy used at rest.

Expressing energy expenditure with metabolic equivalent MET is a very good method showing intensity of physical work. In the generated report it is clearly visible that the examined person for most of the time of the examination (2 hours 34 minutes) was in the range of 3-6 MET, next for 1 hour and 41 minutes in the range of 6-9 MET followed by the toughest range, in which energy expenditure exceeded MET tenfold.

CONCLUSIONS

The use of modern devices, which are currently available on the market, and the measurement methods of energy expenditure give a wide range of capabilities in analysis and assessment of intensity of physical work, especially in production workplaces and in places, where physical work constitutes large part of a worker's duties.

The assessment of energy expenditure conducted by the authors of this article allows to state, that the work performed in the workplace of a feller is a very intensive work. Energy expenditure exceeding 10000 kJ during a shift of 8 hours is a very big expenditure and indicates a high level of inconvenience of the work. Because of this assessment it is necessary for the employer to provide a required prophylactic meal and drinks, which results from the government's disposition regarding prophylactic meals and drinks(Rozporządzenie Rady Ministrów z dnia 28 maja 1996 r. w sprawie profilaktych posiłków i napojów).

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Streszczenie: *Ocena bezpieczeństwa i uciążliwości warunków pracy na stanowisku drwala/pilarza, z wykorzystaniem nowoczesnych metod pomiarowych.* Przedstawiono analizę zagadnień związaną z tematyką szeroko pojętej nauki jaką jest ergonomia. Rozważania autorów skupiają się wokół oceny uciążliwości pracy pracownika na stanowisku drwala/pilarza z szczególnym uwzględnieniem implementacji nowoczesnych metod pomiarowych. Artykuł miał na celu również ustalenie czy urządzenie Body Media Sense Wear oraz POLAR V800 i oprogramowania Polar Flow, są przydatne do monitorowania parametrów aktywności fizycznej pracowników branży drzewnej, w przebiegu diagnozy obciążenia ich pracą.

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