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Journal of Management Systems, 6 issues per year

Publisher:
Romanian Society for Quality Assurance, Bucharest, Romania
President: **Dan Grigore Stoichițoiu**

Indexed in: **WEB OF SCIENCE – ESCI, SCOPUS, EBSCO, PROQUEST** and listed in **CABELL'S Whitelist**

Publisher and Journal address:
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Print:
S.C. Interbrand Impex S.R.L.

p-ISSN 1582-2559; e-ISSN 2668-4861; ISSN-L 2668-4861

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Vol. 21, No. 174 - February 2020

Worker's Metabolic Rate Assessment during Weeding

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Abstract

Green area management, as well as any other agricultural activity in general, is one of the working sectors where professional accident and disease occurrence is considerably high. The existing regulatory obligations take into account the worker's welfare in a wide sense. However, a new attention is paid towards the ergonomic aspects beside the traditional risk agents. Among the factors affecting the worker's psychophysical wellbeing, the aerobic metabolism engendered when carrying out specific duties in agriculture and the stress that goes with it constitute an important aspect. Through the evaluation of some functional parameters of the human body and by analysing the breathing values, heart rate and the amount of oxygen consumed during an activity, it is possible to determine the physical stress it is subjected to. Indeed, the present work focuses on this issue, and aims to evaluate the energy consumption of workers during a green area maintenance using a brush cutter, in order to assess whether the work carried out complies with the parameters set according to UNI EN ISO 8996. The experimental trial was made up of two men, whose average age was 30 years, with a body weight of 78 ± 2.00 kg, a height of 1.71 ± 0.15 m. The results of operators' metabolic parameters recorded by the portable metabolimeter, while performing the green area management using a brush cutter, corresponded to a VO_2 of 48.04 lO_2h^{-1}, a VCO_2 of 43.32 lCO_2h^{-1}, and a heart rate of 98±17 beats per minute. The average operators' metabolic rate (M) corresponding to 143 Wm^{-2} was in line with the tabulated values of energy metabolism at level 1'screening'.

Keywords: *metabolic rate, oxygen consumption, heart rate, occupational illness, agriculture.*

1. Introduction

Within the ergonomics of thermal working environments, the assessment of metabolic activity is an aspect of increasing interest. This is particularly relevant to agriculture, where workers are exposed to a greater risk of occupational illnesses, by virtue of the heterogeneity, as well as the multiplicity of the tasks to be performed, which are mainly carried out in the open field (Ventura & D'Auria, 2014).

In fact, through the assessment of energy metabolism it is possible to measure the muscle load energy consumption, and thus to determine the effort resulting from exposure to a specific thermal environment during the performance of a specific activity.

For example, with reference to weeding control, workers have to cyclically carry out several repetitive physical activities. Quantifying the risks they are exposed to (Iofrida et al., 2018) such as, among others, vibrations (Bernardi et al., 2018, Aiello et al., 2012) and postural problems (Gómez-Galán et al, 2017; Gómez-Galán et al., 2018) becomes crucial. Furthermore, brush cutters are among the most used devices to perform this operation. If on the one hand they have been widely employed because of their affordable prices and ease of use, on the other hand they are often the cause of both direct and indirect accidents (Okubo et al., 2013), which can generate symptoms appearing even after several years.

The knowledge of these critical issues is therefore essential to intervene, in order to increase and ensure the operators' well-being, and a growing attention must be given to the systems used for their correct assessment.

The UNI EN ISO 8996:2005 standard establishes that total energy consumption while performing an activity, i.e. energy metabolism, is assumed to equal thermal energy production, and provides four different levels for its determination (screening, observation, analysis, expertise), each corresponding to a different degree of accuracy (Del Ferraro & Molinaro, 2010).

In the first and second level, the determination is carried out through a classification by type of occupation or activity, or by including other factors such as duration, climbs exceeded, distances travelled, number of actions performed and weights manipulated during operations. Error probability is high for both levels. The third level is based on heart rate recordings over a representative period and under defined conditions; it allows to obtain an indirect determination of metabolic rate and is more precise than the previous ones. Instead, the fourth level, expertise, consists of three methods: measurement of oxygen consumption, which is still divided into partial method (to be used for light and moderately heavy work) and integral method (for heavy and short-term work), doubly labelled water method and direct calorimetry method.

The following study was carried out with the aim of determining the extent of metabolic consumption, assessing it through the expertise level, based on the oxygen consumption instrumental measurement (partial method) of two operators during ordinary weeding activities in a kiwi plant, performed by using a brush cutter.

2. Materials and Methods

Energy metabolism was calculated by applying the following equations reported in the UNI EN ISO 8996:2005 standard.

$$RQ = \frac{VCO_2}{VO_2} \quad (1)$$

$$EE = (0.23RQ + 0.77) \times 5.88 \quad (2)$$

$$M = EE \times VO_2 \times \frac{1}{A_{DU}} \quad (3)$$

Where: RQ – respiratory quotient; VO_2 – hourly oxygen consumption, in litres of oxygen per hour; VCO_2 – hourly consumption of carbon dioxide, in litres of carbon dioxide per hour; EE – Energetic Equivalent, in watt-hour per litre of oxygen $Wh(lO_2)^{-1}$; M – energy metabolism, in watts per square metre; AD_U – Area of body surface, in square metres, provided by the DuBois formula:

$$AD_U = 0.202 \times W_b^{0.425} \times H_b^{0.725} \quad (4)$$

Where: W_b – body mass, in kilograms; H_b – body height, in meters.

As explained in the aforementioned standard, both the stationary regime, achieved after a period of 5 minutes (preliminary period), during which the work is carried out at low intensity, and the main period (of full activity) for a period of 10 minutes, were monitored using regular, seamless samples.

The Cosmed K4b2 portable metabolimeter was used as shown in Fig. 1. After appropriate calibration (Parr et al., 2001), it was fixed to the operator's body through a special harness that favours freedom of movement. The portable unit consists of a display allowing a real-time monitoring of the following parameters: ventilation per minute (VE), oxygen intake (VO_2), carbon dioxide production (VCO_2), difference between oxygen and carbon dioxide (RQ), heartbeat (HR), ambient temperature and atmospheric pressure.

The experimental trial, carried out by two men whose average age was 30 years, with a body weight of 78 ± 2.00 kg, a height of 1.71 ± 0.15 m, was carried out during the mowing operations to remove the turf grass of the sub-row in a kiwi plant. Recorded weather conditions showed an average temperature of 30°C, with relative humidity of 60% and barometric pressure of 790 mmHg. During the tests a STIHL brush cutter (model FS87R) was used.

Figure 1.
Operator equipped with Cosmed K4b2 portable metabolimeter

3. Results and Discussion

Data analysis showed that the volume of oxygen consumed (VO_2) during the entire time span of the tests was on average 48.04 lO_2h^{-1}. Considering separately the planned monitoring phases, this value is on average equal to 43.38 lO_2h^{-1} during the stationary phase i.e. that of low initial activity, and reaches the average value of 54.18 lO_2h^{-1} during the main period.

With reference to the average volume of carbon dioxide produced (VCO_2), this was equal to 43.32 lCO_2h^{-1}. During the stationary phase it assumes the value of 39.62 lO_2h^{-1}, while during the main period it is 48.36 lCO_2h^{-1}.

As regards the heart rate, this was on average 98 ± 17 beats per minute (bpm), while the maximum recorded was 150 bpm.

Fig. 2 separately shows the values of VO_2 and VCO_2 for the two operators, during the entire sampling period. Different performances have been recorded, since operator A registered the highest values.

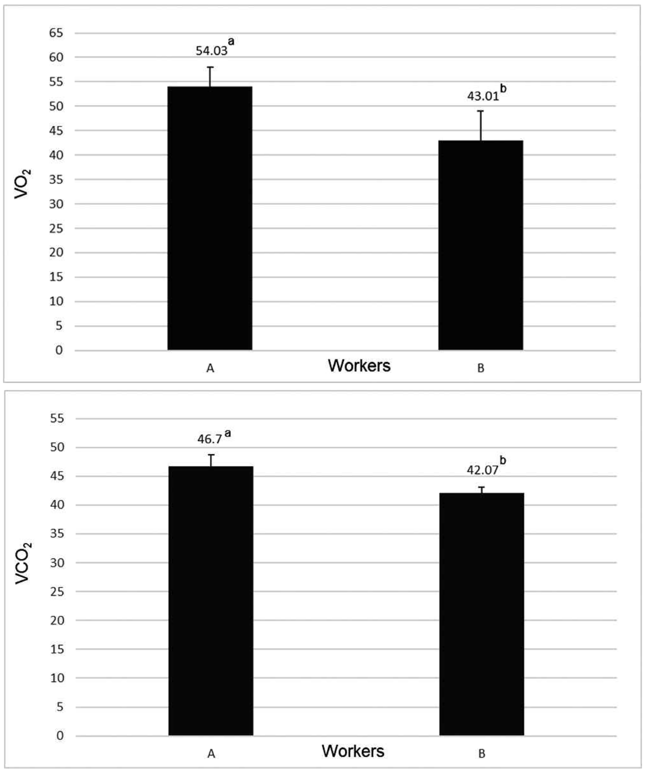

Figure 2. Average volume of oxygen consumed (VO_2) and carbon dioxide produced (VCO_2). Different letters indicate significant differences at the *t*-test (*P*> 0.05).

Regarding the energy metabolism (M), calculated as shown in equation [3], it is equal to 159 Wm^{-2} for operator A and 118 Wm^{-2} for operator B, respectively equivalent to 136 and 101 kcal $h^{-1}m^{-2}$.

Considering an average working day of 8 hours, the final energy consumption will therefore be 1088 kcal $h^{-1}m^{-2}$ for operator A and 808 kcal $h^{-1}m^{-2}$ for operator B.

As a comparison, and with reference to agricultural works, Callea et al. (2014) found that the values of energy metabolism were 200–260 Wm^{-2} for apple harvesting operations. Yadav et al. (2010) highlighted that the physiological cost for a male employed in weeding-by-sickle operations was in average 15.92 kJ min^{-1}; while it was 14.14 kJ min^{-1} for a female employed in manual weeder operations. It can be stated that weeding by sickle and weeding by weeder respectively come under moderately light and moderately heavy work.

Comparing the analysed data with the tabular data reported in the UNI EN ISO 8996:2005 standard (Table 1), which at level 1 performs a classification of energy metabolism subdividing it into 'categories' (method 1B), energy consumption related to the type of tests carried out fully comes under the 'moderate' class.

These values are also confirmed by the further classification 'by type of occupation' (method 1A), according to which this comes under the 'agriculture' sector and 'gardener' field (115 to 190 Wm^{-2}).

Class	Average metabolic rate (with range in brachet) Wm^{-2}
0 Resting	65 (55 to 70)
1 Low metabolic rate	100 (70 to 130)
2 Moderate metabolic rate	165 (130 to 200)
3 High metabolic rate	230 (200 to 260)
4 Very high metabolic rate	290 (>260)

Table 1. Classification of metabolic rate by category at level 1, screening (method 1B)

4. Conclusions

The management of green areas and weeding in particular is today a topic of great interest, and it is often more addressed to assessing the effectiveness of the treatment than to quantifying the risks the operators can incur.

Among these risks, which are rarely adequately evaluated, there are the kinetics of energy consumption, which take particular interest especially during open field work, when operators are subjected to a sometimes excessive energy consumption in relation to the type of performed work.

The agricultural branch in general is in fact one of the working sectors in which the probability of accidents, as well as the onset of occupational diseases, is higher. The current regulatory obligations provide for the protection of worker's wellbeing in an overall sense: alongside traditional risk agents, a new attention is paid on the so-called ‘ergonomic’ aspects, which affect the worker’s psychophysical wellbeing (Tuure, 1992).

The present study was carried out from this point of view. It assessed a standard working condition (acceptable temperature, flat terrain, etc.), performed by workers in full strength. However, if the tests had been carried out, for example, in severe environmental situations (hot and cold), the climatic conditions could have compromised, even heavily, the operators’ health. In such environments, for instance, the thermoregulation system of human organism is subjected to a heavy effort in order to maintain the necessary thermal equilibrium.

In order to better protect operators in the agricultural sector, by virtue of the several inherent risks, it is essential to increasingly tend towards a multidisciplinary vision, focusing on aspects which are often considered secondary. Nevertheless, in recent years the steps forward made by research in this field are noteworthy; they have had the advantage of encouraging also manufacturers to search for more and more valid and rational solutions, aimed at ensuring greater safety of workers, a goal that must increasingly be a priority for all.

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