Arh. hig. rada toksikol., **30** *(1979) suppl. pp. 1331–1337.*

A METHOD FOR ESTIMATING ENERGETIC REQUIREMENTS IN DIFFERENT WORK ACTIVITIES

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ABSTRACT

Different working tasks were assigned to 10 workers, in a study to assess the relationship between volume-minute and caloric output. Based upon this an equation of general regression was plotted, having the energy expenditure (Y) as dependent variable. The regression equation was determined for each one, and all were compared so as to know if the differences were relevant.

Five new workers undertook certain assignments, and the energy expenditure was determined by using the equation of general regression and three equations that had been determined by some authors in different occupational groups. Statistical assessments are made and a formula for estimating the caloric requirements of most working activities is proposed.

In order to establish, from the physiological point of view, a worker's maximum aerobic capacity (maximum oxygen consumption) it is necessary to have in mind the caloric requirements of his work activity during 8 hours. For the determination of this several practical methods have been suggested which are easy to carry out due to their simplicity and low cost[1]. One of the methods consists in the design of a nomogram, prepared according to the principles stated by other authors[1,6], which also includes the climatological characteristics of Cuba and the anthropometric qualities of Cuban workers[5]. This procedure, established according to the linear relation between cardiac rate and oxygen consumption under a sub-maximum work load, is very simple and economical and can be applied in any work centre of the country.

Several methods have been suggested for determining the caloric requirements of a work activity. The most common method consists in collecting the air exhaled during work and analyzing its gas contents in order to determine the oxygen consumption and estimate from it the caloric output. This is a difficult process which requires certain material and human resources which increase its cost. Another method is the use of the cardiac rate registered during a specific activity. However, it has been proved that despite the close relation between this variable and the caloric output, there exists a different two-component relation in every individual even while doing the same type of work[4].

Several authors[2,3] have proposed the use of the respiratory minute-volume (MV) as a physiologic variable to estimate the caloric output.

A regression equation calculated for a group of workers doing the same job has proved useful and fairly accurate in determining the caloric output in other workers who carry out a similar activity. Data proved that the estimation of the caloric output using the minute volume, in a number of workers doing the same work, is more accurate than that when using the cardiac rate, and he proposed a simple formula which relates the caloric output to the minute volume based on the relation $y = m\ (x)$.

According to these principles we intend to estimate a regression equation in order to prove its value as a caloric output estimation method, and compare it with the other equations presented for different occupational groups.

SUBJECTS AND METHOD

Different work loads were imposed on 10 healthy male workers, starting from the position of rest. The work loads were carried out on a 50 cm high wooden bench with an intermediate step.

After the measurements in the state of rest, each worker climbed on the bench at a three step rhythm: 16 times/minute for the first load and 20 times/minute for the second. In both loads the total climbing time was 6 minutes. The exhaled air was collected during the minute expired between the 5th and the 6th minutes, when the individuals had achieved their standing or equilibrium state. The exhaled air was collected into a Douglas bag. Two samples were drawn from each bag and analyzed in a gas microanalyzer (Scholander) to determine the O_2, CO_2 and N_2 contents in order to estimate the actual oxygen consumption in the state of rest and under a work load. Subsequently, the contents of each bag were tested in a gas meter. The energetic equivalent used for oxygen was 1 litre = 5 Kcal.

The anthropometric data of 10 studied subjects aged 21 ± 2.3 (17–24) were: body weight 65 ± 8.6 kg (54–84 kg), height 170 ± 4.5 cm (165–180), body surface 1.7 ± 0.1 m^2 (1.6–2.0). The study was carried out on workers of a cardboard factory whose daily work could be considered as light or moderate.

The experimental room was kept at room temperature in order to reproduce the climatic conditions prevailing in Cuba. The measurements carried out in the room before every work load in order to estimate the effective temperature and the relative humidity percentage showed dry temperature 27.6 ± 1.0 °C (26–29 °C), wet temperature 25.0 ± 1.5 °C (21–27 °C), barometric pressure 761 mm Hg (760–762 mm Hg) and a relative humidity of 80%.

Subsequently, five other individuals were studied. They were assigned a work load, and their caloric output was estimated according to the regression equation calculated before. The air collection and gas analysis procedures and the time period of work were similar in both cases, and the only variation found was the intensity of the load imposed. Finally, the calculated regression formula was correlated to that of other authors, and several suggestions were made regarding its application.

RESULTS AND DISCUSSION

Table 1 shows the data on oxygen consumption and minute volume established at different moments of the investigation. The oxygen consumption mean values ranged from 188 to 1 622 ml/min, representing an activity range which starts from rest and goes up to extremely active work. The corresponding minute volume values were from 6.3 to 45 l/min, with standard deviation values from 0.8 to 7 l/min, respectively.

TABLE 1
Physiologic variables measured during the rest period and under two work loads.

	VO_2 (STPD)			M.V. (STPD), l/min		
	$\overline{X}$	S.D.	Range	$\overline{X}$	S.D.	Range
Rest	188	34	(143 – 278)	6.3	0.8	(6 – 8)
1st load 512 kg/min	1 021	214	(721 – 1 395)	25	4	(20 – 31)
2nd load 640 kg/min	1 622	174	(1 367 – 1 923)	45	7	(35 – 59)

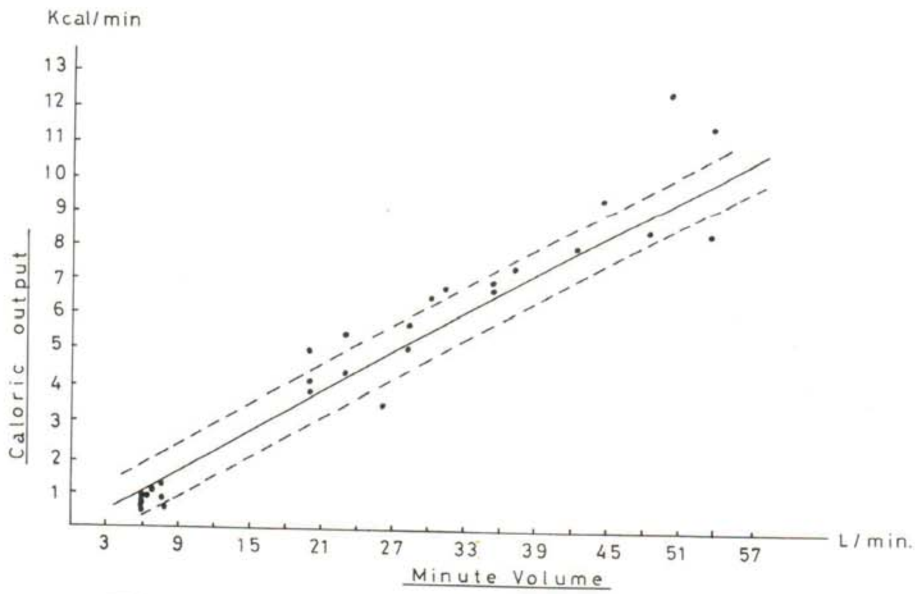

FIG. 1 – Minute volume and caloric output under different work loads.

Figure 1 shows the minute volume values with the corresponding caloric output values once the oxygen energetic equivalent was used up. The central line represents the regression equation, and the side lines ± S.D. from it.

The correlation value (r) between the minute values and the caloric output was as high as 0.95, which relates well to the figures reported by other authors[2,3]. The standard error (0.46) is also fairly similar to those found in previous works. This fact proves that the general regression equation which is worked out in order to predict the values of the dependent variable (caloric output) in any individual who carries out the same activity can also be used for a group of individuals who carry out the same activity.

On the basis of the facts mentioned above, 5 new individuals were subjected to a work load consisting of going up and down the wooden bench during a specific time period. The collection of the exhaled air as well as the estimation of the actual oxygen consumption for each activity were carried out by means of the same method.

Table 2 shows the five individuals, the work performed and the kilo-calories used in one minute. The latter were calculated according to the oxygen used in the exercise. Together with the data on the exhaled volume per minute STDP (dry temperature and standard pressure), the previously calculated regression formula ($E = 0.08 + 0.183$ MV) was used in order to estimate the caloric output value and to make a comparison with its actual value.

TABLE 2
Work performed and caloric output in five new cases.

Subjects	Work performed (kg/min)	Caloric output (Kcal/min)
K	600	5.3
L	512	4.85
M	405	4.0
N	540	6.8
O	465	5.7

With our MV data we also estimated the caloric output by means of the regression equations proposed by Rao[8] for agricultural workers in India ($E = -0.887 + 0.230$ MV) and for textile workers in that country ($E = -0.270 + 0.184$ MV), as well as by means of the equation ($E = 0.480 + 0.170$ MV) proposed by Sen Gupta and co-workers[9] for estimating the caloric output of workers in a jute mill. The following was proved by the use of these four formulas, including ours: the S.E. of the difference was fairly similar in the four equations and showed values from 0.15 to 0.18. In the four equations, the correlation (r) was 0.92, and the established differences had no significant value. The error percentage resulting from the four equations produced a negative value in all of them, the highest being -13.15. As Table 3 shows, the percentage standard deviation was slightly uniform; thus we may state that in our study from an estimated value of 4.9 Kcal, only 5 out of 100 cases will have values under 4.2 Kcal or higher than 5.5 Kcal ($\pm 6.7\%$).

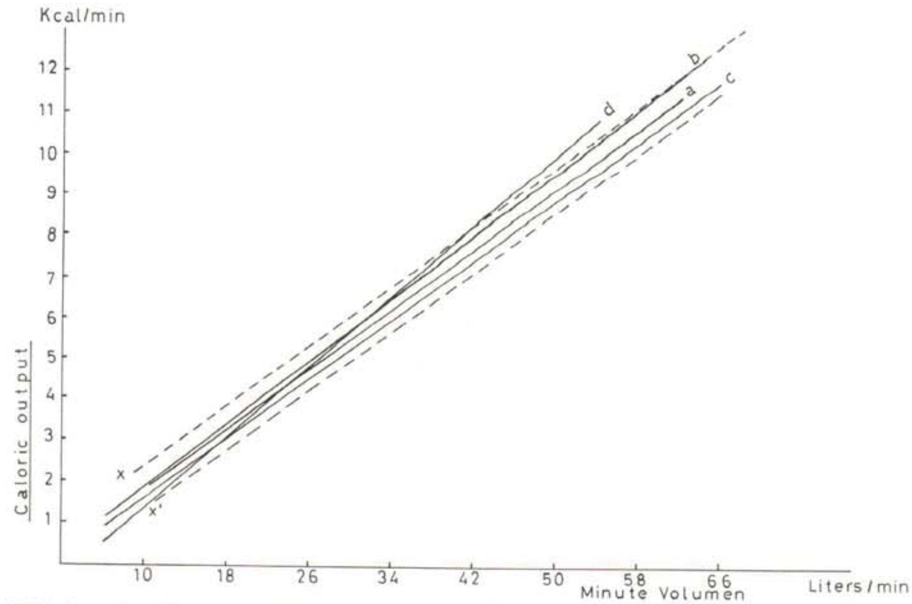

FIG. 2 – Graphic representation of the regression equations.

Legend: a. – Regression line of the present study.
b. – Regression line for agricultural workers (Rao 1)
c. – Regression line for textile industry workers (Rao 2)
d. – Regression line for mill workers (Sen Gupta)
XX' – ±S.D. of the present study.

Figure 2 shows in the XY axis the 4 regression equations including ours. At both sides of the line we can see a broken line representing ±S.D. of it, which corresponds to the graphic representation of our own regression equation. All the remaining regression lines remain within both tracings from approximately 10–46 litres values of the minute volume. This is consistent with the investigations made by other authors (the correlation is higher for the minute--volume and caloric-output intermediate values than for the lower and higher values). This may be due to the fact that the respiratory efficiency is not constant at every work level, and very high values of the minute volume may be found together with proportionally lower values of oxygen consumption and thus also of caloric output[10].

All this suggests, according to this study and to the reports of other authors[7], that the estimation of the caloric output by means of the minute volume is most accurate in the 12–42 l/min values. This is a happy coincidence, as most work activities are within this minute value range.

We developed Table 4 according to a detailed analysis of the four regression equations represented in Figure 2. This Table shows the necessary kilo--calories/minute for each work grade, classified in four main stages. For each

TABLE 3

Estimation of caloric output (E) by minute volume (M.V.) using the regression equations determined in different occupational groups.

References	E.V.(*)	A.V.(**)	Difference ± S.E.	R.value	Sign	Error (%)	S.D. (%)
Rao (1) 1965	5.18	5.32	0.14 ± 0.15	0.92	0.25	− 2.08	6.6
Sen Gupta, 1959	4.97	5.32	0.35 ± 0.19	0.92	0.71	− 4.8	7.5
Rao (2) 1965	4.58	5.32	0.74 ± 0.18	0.92	0.84	−13.15	6.7
Present study	4.90	5.32	0.42 ± 0.18	0.92	0.84	− 6.9	6.7

(*) Caloric output estimated value in Kcal/min
(**) Caloric output actual value in Kcal/min

TABLE 4

Caloric output and minute volume for different work grades.

Grades	1	2	3	4
Kcal/min	2.28	2.90	3.95	5
Vol/min (STPD), l/min.	10 – 13	14 – 17	18 – 23	24 – 30

grade modality there is a minute volume range in litres. As can be seen, an individual maintaining a 24-litre or more minute volume will be doing an extremely active work, regardless of the work intensity decreasing within the next minutes. For this reason, in evaluating the caloric needs for any activity, we consider it important to collect several samples of the air exhaled during the most active and least active moments, in order to classify the job according to the caloric requirements during an 8-hour working day.

CONCLUSIONS

There is no doubt that, the use of the minute volume as a physiological variable for the estimation of caloric output is very useful for field investigations, whenever it is necessary to know the exact caloric needs required by a particular work activity. Certainly, there are several jobs where the collection of the exhaled air volume is very difficult, but the method can be used in most production and service activities.

We must take into account various factors which may influence the relation between the minute volume and the caloric output, such as age, sex, and level of training. In this respect we regard it necessary, in evaluating the caloric requirements of any work place, workshop or factory, to make a previous selection of the workers, and group them according to these characteristics; emphasis should be placed mainly on the level of training, which may be established by making questions regarding the time period during which the worker has been doing the respective task, the type of physical exercise practiced, and his previous jobs.

Prior to an investigation, a study on the work life should be made in order to establish the "peak" moments of intense work, the production flow, meal hours and rest periods. It should be remembered that an activity considered extremely intense at a particular moment may prove to be moderate during an 8-hour working period.

The collection of exhaled air may be done using a Douglas bag during a period of time the investigator considers adequate for the job, and the conversion to one minute can be made after the collection. The number of exhaled air samples should be in proportion to the difficulty of the respective job. In order to establish the volume of the exhaled air, the bag contents should be tested in a properly gauged air meter. In order to calculate the STPD correction factor, the dry temperature and the barometric pressure must be measured.

The proposed equation: Caloric output (Kcal/min) = 0.08 + 0.183 M.V. (l/min STPD) may be used in the case of male individuals 17 to 30 years of age. This equation not only provides information on the caloric requirements of an activity, but also allows us to make comparisons between individuals doing the same work, in order to establish the training degree achieved. Finally, we may state that as regards accuracy, this method is no substitute for direct measurements of caloric output, but if we consider the aspects discussed above, the limited resources needed for its application, and the important information it provides, the procedure may be regarded as very useful for field measurements.

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