COMPARISON OF HEART RATE AND FACTORIAL METHOD MEASUREMENTS FOR PREDICTING ENERGY EXPENDITURE IN WORKING LACTATING EWES

PERBANDINGAN METODE DENYUT JANTUNG DENGAN FAKTORIAL UNTUK MENGUKUR ENERGY EXPENDITURE PADA DOMBA KERJA LAKTASI

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ABSTRACT

The use of conventional gaseous exchange methods for measuring animal energy expenditure is technically difficult and not generally feasible for animals working under field conditions. This experiment was held to study comparison of heart rate and factorial method measurements for predicting energy expenditure in working lactating Merino ewes. The ewes used were two years old, having similar liveweight and body condition, and given *ad libitum* mixed feed of sorghum and lucerne hay containing 13% of crude protein. The "*Working*" ewes was placed on modified horse treadmill with speed of 0.9 m second^{-1}, 3 hours, load of 10% liveweight, and 0^{o} incline; whereas the *"Control"* ewes were standing adjacent to opposite group. Energy expenditure was done using *Heart-rate* method and *Factorial* method. Heart rate was through measuring air bubble pulse created within the stream of heparinised saline in the jugular catheter. It was observed that mean energy expenditure estimated by using the *Heart-Rate* method was higher than that derived by the *Factorial* method and energy expenditure of *Working* ewes was higher than that of their *Control* counterparts, during both *Work* and *Recovery* periods.

Key words: ewes, energy expenditure, heart rate method, factorial method,

ABSTRAK

Pengukuran energy expenditure secara konvensional dengan menggunakan metoda pertukaran gas secara teknis sangat sulit dilakukan dan sangat mahal apabila dilakukan pada ternak kerja pada kondisi lapangan. Penelitian ini mengevaluasi estimasi pengukuran *energy expenditure* dengan menggunakan metoda denyut jantung dan metoda faktorial pada domba betina kerja yang sedang laktasi. Pengukuran dilakukan pada delapan domba Merino betina yang sedang laktasi dengan berat dan ukuran tubuh yang sama dan umur dua tahun. Pakan yang diberikan adalah campuran hay sorghum dan lucerne dengan kandungan protein kasar 13% dan diberikan *ad libitum.* Kelompok *"Kerja"*, dengan kategori kerja "ringan", dilakukan dengan menempatkan domba diatas *treadmill* khusus untuk kuda yang telah dimodifikasi (kecepatan 0.9 m detik^{-1}, lama 3 jam, beban equivalent dengan 10% berat badan ternak, and kemiringan *treadmill* 0^{o}), sedangkan domba *"Kontrol"* sama sekali tidak melakukan kerja. Pengukuran *energy expenditure* dilakukan dengan metoda *Denyut Jantung* dan metoda *Factorial*. Denyut jantung diukur dengan cara menghitung jumlah gerakan cairan saline pada katether jugular. Hasil penelitian menunjukkan bahwa hasil pengukuran energy expenditure dengan metoda *Denyut Jantung* secara signifikan lebih tinggi dibanding dengan metoda *Factorial*. Energy expenditure domba *"Kerja"* juga ditemukan lebih tinggi dibanding domba *"Kontrol"* baik pada saat kerja ataupun saat selesai kerja.

Kata kunci: domba betina, energy expenditure, metoda denyut jantung, metoda faktorial

INTRODUCTION

Increased muscular activity in animals results in both increased metabolic rate and body temperature. A working animal, therefore, will require an extra amount of energy (for muscular work) above that required for maintenance. For example, the extra energy required by an animal for ploughing could amount to 3.8 times its basic metabolic rate (Leng, 1985). The amount of energy required to perform such work is influenced by factors that include work duration and intensity, environmental conditions under which the work is performed, and animal live weight (Bamualim and Kartiarso, 1985).

The use of conventional gaseous exchange methods (Brouwer, 1965) for measuring animal energy expenditure is technically difficult and not generally feasible for animals working under field conditions. Lawrence (1985) countered such difficulties by developing a *Factorial* method of estimating energy expenditure which involves the measurement of a number of factors. In a number of earlier studies, however, energy expenditure was predicted simply from heart rate measurement. Webster (1967) for example, applied the technique to non-working sheep while Yamamoto *et al.* (1979) applied it to non-working cattle.

The application of predictive equations using heart rate measurements for estimating energy expenditure in working animals was first described by Richards and Lawrence (1984) who demonstrated a positive linear relationship between the heart rates of working oxen and buffaloes and the respective amounts of energy expended by those animals. While it is uncertain whether the equations developed from such studies are applicable to working sheep, there seem to be no compelling reasons to suggest otherwise, because physiological and metabolic responses to work in small and large ruminants are considered to be very similar (Biswas *et al.*, 1991).

This current experiment was undertaken to evaluate that the heart-rate method for estimating energy expenditure would yield the same results as those yielded by the Factorial method when both methods are applied to working lactating ewes.

METHODOLOGY

The study was conducted in the School of Biomedical and Molecular Sciences, James Cook University of North Queensland, Australia for 4 months started in January, 2000.

Sixteen ewes were used in a Randomised Block Design in the experiment. The ewes were divided into two groups of eight ewes, evenly matched for live weight and body size. One group was randomly assigned to the *Working* treatment and the other group, the non-working treatment (*Control*).

The animals used were lactating Merino ewes, two years of age, with a mean live weight of 37 $\pm$ 4 kg, and each with a single lamb. All the ewes were accustomed to experimental conditions and kept in metabolism cages. Their lambs were also kept in metabolism cages adjacent to their respective mothers and were allowed to suckle twice a day at 0900 h and 1600 h.

The diet was a mixture of sorghum and lucerne hay with a crude protein content of 13%. The feed was offered at 120% *ad libitum* intake at 1600 h each day. Mineral blocks and clean drinking water were available at all times.

A polyethylene catheter was installed in an external jugular vein of each ewe in order to facilitate pulse rate counting while two pairs of *Working* ewes were subjected to three hours work (0900 - 1200 hours) on the treadmill each day. The work regime was categorised as *light* work using the *Factorial* method of estimating energy expenditure (walking speed 0.9 m second^{-1}, walking duration 3 hours, load pulled equivalent to 10% of live weight, and treadmill incline 0^{o}). Heart rate or pulse rate was recorded for each animal and were taken at 30 minute intervals, an hour before work started (*Pre-Work*), during the three hours of work (*Work*) and in the first of the three hours immediately after work stopped (*Recovery* period). In the last two hours of the *Recovery* period, the pulse rate was recorded at hourly intervals. Two *Working* ewes were paired with two *Control* ewes, which remained in metabolism cages and for which recordings of variables (listed above) were taken simultaneously to those of the *Working* pair.

All measurements were taken over a period of six consecutive days and *Working* ewes were categorized as in fatigue if the rectal temperature reached 41 ^{o}C or above resulting in removing from the treadmill and returned to their respective cages.

Energy expenditure of *Working* ewes was estimated using Lawrence's (1985) *Factorial* method developed by Richards and Lawrence (1984) - See below for details:

$$EE^{W} = 24.94\ RHR - 16.25$$

Where :

EE^{W} = actual energy expenditure per unit metabolic body weight (watts $kg^{-0.75}$)

RHR = heart rate of the working animal/heart rate at rest.

Energy expenditure for the *Control* ewes was calculated according to MAFF (1984) as follows:

$$M_{m} = 1.4 + 0.09\ W$$

where :

W= is live weight (kg) and M_{m}= MJ day^{-1}

Data were subjected to T-Test and one-way analysis of variance (ANOVA – Daniel, 1991) using SPSS for Windows release 11.0 (SPSS Inc., USA). In cases where ANOVA showed significant effects of treatment, mean values were compared using the Least Significance Difference (LSD) test (Daniel, 1991). The P values obtained by using SPSS for Windows are presented to three decimal places only.

RESULTS AND DISCUSSION

Heart-rate vs Factorial methods

Means of energy expenditure estimated from heart rate values (Richards and Lawrence, 1984) and from the *Factorial* method (Lawrence, 1985) for *Working* ewes are presented in Table 1.

As ambient temperature, rates of heat absorption and loss and relative humidity appeared to have had a significant influence on heart rate values during the experiment, mean values for energy expenditure obtained by means of *Heart-rate* method were corrected for such factors as shown below:

It was assumed that initial heart rate (HR) value of *Control* ewes measured during the *Pre-Work* period was the HR value which had been least affected by environmental variables. Consequently, this HR value was then used for correcting the HR value of *Control* ewes. This was achieved by subtracting the HR value of *Control* ewes measured during the *Work* period from the initial HR measured during the *Pre-Work* period. This subtraction value (referred to here as "HR_0"), was then used for correcting the HR value of *Working* ewes during the *Work* period; by subtracting the HR value of *Working* ewes during the *Work* period from HR_0. The corrected HR value was then used for calculating the corrected EE. On average, it was found that increasing values of environmental variables observed in the current experiment raised the value of the heart rate by approximately 4.53 beats/min. It was also calculated that EE based on heart rate without correction for 3 hours work during the present experiment would be 2.4 $\pm$ 0.23 MJ.

Mean energy expenditure estimated by using the *Heart-rate* method was higher than that derived by the *Factorial* method (Table 1). Given that the estimated ewes' energy requirements for maintenance was 4.83 MJ d^{-1}, total energy expended by *Working* ewes might be calculated as being 1.5 (4.83 + 2.23/4.83) and 1.4 (4.83 + 1.91/4.83) times maintenance energy values obtained using the *Heart-rate* and *Factorial* methods respectively.

Working vs Control

Unlike data presented in Table 1, energy expenditure values in Table 2. and Figure 1. were presented in uncorrected values because the heart rates of *Control* and *Working* ewes were measured at the same time.

Table 1. Means ± standard error of means (SEM) of energy expenditure by *Working* ewes (MJ) estimated by *Heart-rate* and *Factorial* methods during the three hour *Work* period

	Heart-rate		*Factorial*		P
Activity	Mean	± SEM	Mean	± SEM	
Work	2.23*	0.24	1.91	0.06	0.040

* Corrected value.

Table 2. Means ± standard error of means (SEM) of live weight (kg) and energy expenditure (J/sec./kg$^{0.75}$) calculated from heart rate values recorded during *Work* and *Recovery* periods for *Control* and *Working* ewes.

	Control		Working		P
	Mean	± SEM	Mean	± SEM	
*Work**	9.12 a	0.251	17.51 b	0.993	0.001
*Recovery**	9.62 a	0.467	10.36 a	0.406	0.201
P	0.241		0.001		

Means with different superscripts, within either the same column or the same row, differ significantly * uncorrected values

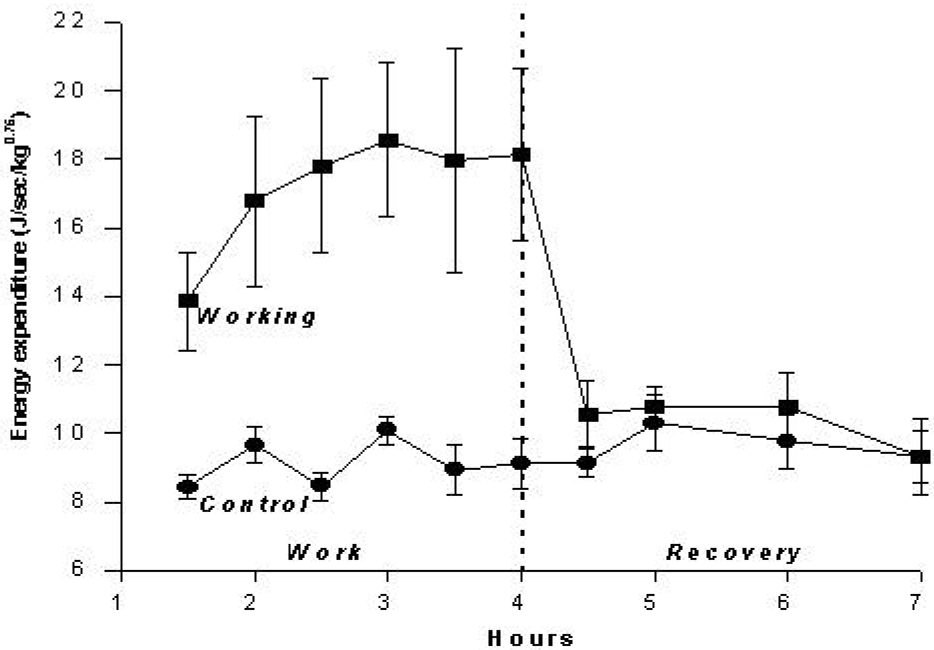

Figure 1. Means (■, ●) ± standard error of means (vertical bars) energy expenditure by *Control* and *Working* ewes as estimated from heart rate values recorded during *Work* and *Recovery* periods.

Energy expenditure of *Working* ewes was higher than that of their *Control* counterparts, during both *Work* and *Recovery* periods (Table 2). Within the *Control* ewes, mean energy expenditure during *Work* and *Recovery* periods was not significantly different. Mean energy expenditure of *Working* ewes, on the other hand, was significantly higher (P=0.001) during the *Work* period than that during the *Recovery* period (Table 2). Plotted values of mean energy expenditure, estimated by using the *Heart-rate* method for *Working* and *Control* ewes, are presented in Figure 1 while Table 2 presents uncorrected energy expenditure values.

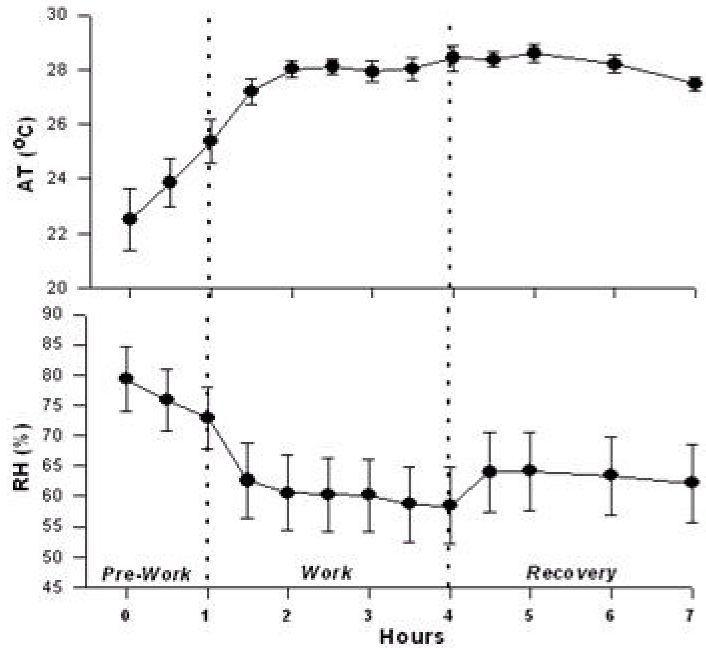

Figure 2. Means (●) ± standard error of mean (vertical bars) ambient temperature (AT) relative humidity (RH) recorded during *Pre-Work*, *Work* and *Recovery* periods.

Energy expenditure of *Working* ewes increased to a plateau by 1.5 hour of the *Work* period, and decreased sharply during the first 30 minutes of the *Recovery* period after which the values decreased steadily so that by the third hour of the *Recovery* period, the mean value was no different (P=0.997) from that of the *Control* group. Energy expenditure of *Control* ewes overall appears to have increased slightly during the observation period (Figure 1).

It is clear from the data obtained that the two methods used for estimating EE by working ewes yield different values with the *Heart-rate* method yielding consistently higher values than the *Factorial* method. Results from other studies using human subjects (Spurr *et al.*, 1988; Ceesay *et al.,* 1989; Livingstone *et al.*, 1990; Emons *et al.,* 1992) have also revealed higher EE values from the *Heart-rate* method compared to values obtained using standard indirect calorimetry methods. In fact, values from the *Heart-rate* method can be as high as 30% more than those obtained through standard indirect calorimetry techniques. In the current experiment, the EE value obtained using the *Heart-rate* method was only 17% higher than that obtained using the *Factorial* method. In the context of total daily EE by the ewes, the significance of the difference between the two methods is somewhat reduced in that the *Heart-rate* method yielded a value of 1.5 times EE for maintenance while the *Factorial* method yielded a value of 1.4 times EE for maintenance. Teleni *et al.* (1991) estimated EE in working animals from values of CO_2 production rate and the regression equation developed by Young (1970) from pooled sheep and cattle data. These authors reported that the technique was a reasonable one for estimating EE. Unfortunately in the current experiment, the accidental loss of CO_2 samples precluded the inclusion of this technique in the comparison of methods.

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Studies on humans have shown, that within certain limits, heart rate increased linearly with increasing AT (Hebestreit *et al.*, 1995). Factors which might explain some of the high values of EE estimated using the *Heart-rate* method on humans (*e.g.*, Dauncey and James, 1979; Kalkwarf *et al.*, 1989) include environmental variables recorded in the current experiment. Indeed, Hebestreit *et al.*, (1995) have suggested that corrections for the effect of climate-related variables on heart rate, could be undertaken to improve the EE estimations using the *Heart-rate* method. In this experiment, the fluctuations of environmental variables (ambient temperature and relative humidity) can be seen in Figure 2.

EE values of 1.4 - 1.5 times maintenance energy estimated by the two methods examined in the current experiment might be classified as values obtained from animals undertaking light work. Indeed, Pearson *et al.* (1989) obtained a value of 1.3 times maintenance in their work with cattle subject to land harrowing (a task considered to be light work). On the other hand, oxen or buffaloes subjected to heavy work could expend energy of 1.7 to approximately 3.0 times maintenance (see Lantin 1964; Lawrence, 1985; Teleni *et al.*, 1991). These animals could be ploughing for 5.5 hours (Lawrence, 1985) or pulling a load with a tractive effort equivalent to 8% their live weight (Lantin, 1964; Teleni *et al.*, 1991).

Environmental variables

Plotted values of mean environmental measurements are presented in Figure 2.

Mean values of AT steadily increased from the *Pre-Work* period to about one hour into the *Work* period, at which point the values remained relatively stable for up to an hour into the *Recovery* period (Figure 2). Mean RH values gradually decreased from the *Pre-Work* period to the end of the *Work* period. There was a slight increase in RH value in the first half hour of the *Recovery* period, after which values remained relatively stable (Figure 2).

No significant variations in environmental variables were recorded throughout the environmental and physiological measurements.

CONCLUSIONS

The *Heart-rate* method for estimating energy expenditure yields higher results than those yielded by the *Factorial* method when both are applied to working lactating ewes. Environmental variables, namely ambient temperature and humidity, would explain the reason for this higher value. Also, energy expenditure of *Working* ewes was higher than that of their *Control* counterparts, during both *Work* and *Recovery* periods.

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