ENERGY EXPENDITURE AND PHYSIOLOGICAL STRAIN OF PITSAWING ACTIVITY IN AGROFORESTRY

Kweka, A. E.

Forest Engineering Department, Sokoine University of Agriculture,
P. 0 Box 3012, Morogoro, Tanzania
Email: aminire@yahoo.com

ABSTRACT

Heart rate is one of the accurate means to evaluate the physiological or functional demands of work on the worker. Hence the study was undertaken to know the workload of manual timber sawing activity. The results revealed that, the cardiac cost of work while sawing was 68.9 beats/min and during recovery was 25.09 beats/min. The average working heart rate during sawing was observed to be 135 (±17.83) beats/min and the average energy expenditure was 12.85 kj/min. The task was classified as heavy work. The energy spent by the topman to pull the saw upwards was 13.36 kj/min which was significantly higher than energy spent by the pitman (10.88 kj/min) when pulling the saw down wards. To minimize fatigue a rest allowance of 28.88 minutes for every 30 minutes of work is recommended. Reduction of workload load can be achieved by improving the hand tools and work environment.

Keywords**:** Heart Rate, Cardiac Cost of Work, Rest Allowance

INTRODUCTION

Many researches postulate that, future increase in timber supply in many countries is expected to come from agroforestry(Haynes 2003; Enters and Durst,2004). Most agroforestry farms are often established with no thought as to how the timber will be extracted at time of harvesting. In addition, the farms are invariably small in size which leads to a higher cost of logging for every tone of logs carted to the mills. Solution to some of these problems has been to process the timber on-farm (Hall 1990). The technology used for on-farm timber processing in many developing countries is ‘pitsawing’.

Pit-sawing is done by two men with a long saw that has cross handles on each end. A log, hewed square, is placed over a pit, or elevated on trestles (Butera and Klem 1983; Richards 1983; and Philip 2001). One man stand on top and pull the saw up while the other stand in the pit below and pull it down. It is used for producing sawn planks from tree trunks, which could then be cut down into boards. Most of the movements during sawing, however, engage large muscle groups which are alternatively contracted and relaxed, and the work is considered to be dynamic.

This sawing technique provides employment and income to many sawyers, timber traders and farmers in the rural area (Madira and Krassowska 2005). Timber products produced smooth out seasonal production/income cycles of the rural people, provide goods and services to the poorer strata of society (which larger industries fail to reach) and they introduce vital skills into rural areas (ILO 1986). As investment opportunity area and the main source of rural employment, manual timber-processing industry appears to be highly accessible to the poor, the landless and other disadvantaged groups (Strehlke 2003).

In spite of continuous technological advance and mechanisation of forestry works, use of machines in agroforestry to replace pitsawing has been encountered by definite limitations due to inaccessibility of the farms (Abeli 2000; Kweka *et al.* 2007). . This implies that improvement of the productivity and reduction of workload of pitsawyers may often lie largely in research on hand tools and working techniques by physiological methods. The aim of this study was to present the analysis of the energy load of pitsawyer employed in selective harvesting of timber in agroforest farms. The study also recommended measure to reduce the hard physical effort, arduousness and harmfulness of the work

METHODOLOGY

Six healthy males performing manual timber sawing activity regularly were selected for the study. Physical characteristics like height and weight were measure using anthropometric rod and weighing balance respectively. Heart rate monitor was tied to every respondent and switched on to record the heart rate at every minute. Subjects were asked to sit in a chair for approximately 15 minutes and resting heart rate was recorded.

Heart rate per minute was recorded when doing sawing activity for 30 minutes and then again 10 minutes rest was given. After which the subjects exchanged their positions and continued the activity for another 30. At the end of the session, the heart rate monitor was detached from the subjects and the data from the monitor was manually transferred to the computer.

Based on the heart rate records the following parameters were calculated.

1. Average heart rate during rest, work and recovery period.

2. The energy expenditure per minute was estimated from heart rate using the following formula and the classification of work load was done as per Varghese *et al.* (1994).

Energy Expenditure (kj/min = 0.159 x Average

3. The Total Cardiac Cost of Work (TCCW) per minute was also estimated based on the cardiac cost of work (CCW) per minute and cardiac cost of recovery (CCR) per minute where:

   $$CCW/\text{min} = \text{IAWHR} = \text{AWHR - ARHR}$$

   IAWHR = increase Average Working Heart Rate

   AWHR = Average Working Heart Rate

   ARecHR = Average Recovery Heart Rate

   CCR/min = IARecHR= ARecHR— ARHR

   IARecHR = Increased average heart rate during recovery

   ARecHR = Average Recovery heart rate

   ARHR = Average Resting Heart Rate

4. To avoid fatigue it was desirable to determine the amount of rest required for sawing task. Rest allowance time was determined with knowledge of the work forces maximum aerobic power (MAP) using the following equation (Bridger, 2003):

   MAP = 200-0.65Age where

   Age = average age of the subjects

Using Rohmert (1973) formula for dynamic work, rest allowance was determined as percentage of the actual task time.

$$\%\text{Resting allowance} = 1.9 \times (\text{Task time in min})^{0.145} \times \left(\frac{\text{Task Energy Expenditure/min}}{\text{Standard Energy Expenditure/min}} - 1 \right)^{1.4} \times 100$$

Table 1: Physical characteristics of the subjects selected for ergonomic evaluation of log sawing activity with hand saw. N=6

S. No.	Physical characteristics	Mean	S. D.
1.	Age(yrs)	33.75	12.09
2.	Height (cm)	1.63	0.04
3.	Weight (kg)	58.75	3.19
4	Resting heart rate (RHR) (beats/min)	66.75	6.18
5	Body Mass Index (BMI) ($\left(kg/l^2\right)$	22.06	1.96

Results and Discussion

The mean age of the respondents selected for the study was 33.75 ± 12.09 years, height was 1.63 ± 0.04 m and weight was 58.75 ± 3.19kgs. The mean resting heart rate (RHR) was 66.75 ± 6.18 while the body mass index (BMI) was 22.06±1.96 (Table 1).

Sawing was performed with a two man ripping saw weighing about 5kg. Sawing was done by applying the push-pull pressure by the hand with topman standing on the log and pitman in the pit. The average heart rate recorded while performing sawing and during recovery period was 135 ±17.83 and 91.84 ± 14.17 beats/min respectively. Sawing activity was therefore classified as very hard work which demanded 12.85 kj/min of energy, while recovery was considered to be light to heavy workload.

Table 2: The average and peak heart rate and energy expenditure of the sawyers while pitsawing

Activity	Working heart Rate (Beats/min)			Energy Expenditure (kj/min)		Classification of work load	
	Average	Peak	Number of. observations	Average	Peak	Average	Peak
Rest	66.75	75.00	6	1.89	3.21	Very Light	Very Light
Sawing	135.65	174.00	187	12.85	18.95	Heavy	Very Heavy
Recovery	91.84	128.00	44	5.88	11.63	Light	Heavy

It is generally held that individuals can work at level of 40% of their maximal aerobic power for 8 hours without suffering undue fatigue. From Table 3, the average working heart rate of the subjects (135.65 beats/min) was compared to the 40% of maximal aerobic power (111.27 beats/min) which indicated that the physiological cost to workers was greater than that which is appropriate for 8-hours. This indicates that the sawing operation should not be performed without rest.

Table 3 Estimated limit of work for the subjects over an eight hours day

Average Age (years)	Estimated MAP (beats/min)	RHR (beats/min)	IAWHR (beats/min)	40% x IAWHR (beats/min)	Allowable HR for 8hrs (beats/min)
33.75	178	66.75	111.31	44.52	111.27

Rest allowance time was determined as percentage of the actual task time. Figure 1 shows the variation of rest time as percentage of the task time. The Rohmert algorithm produces higher resting percentages as the task duration and/or work intensity increases. For the 30 minutes task duration used in this study the rest allowance was 96.1% of the task time which is equivalent to 28.8 minutes. This implies that if the subjects perform the actual task for 30 minutes they have to have a rest of 28.8 minutes to minimize fatigue.

Table 4 presents the Cardiac Cost of Work and recovery per minute and the classification of workload of sawing activity based on heart rate and energy expenditure. The calculation of Cardiac Cost of Work for sawing activity was 68.9 beats/min and during recovery was 25.09 beats/min. As per the average heart rate and energy expenditure the sawing activity was classified as heavy activity and based on peak heart rate it is classified as very heavy activity.

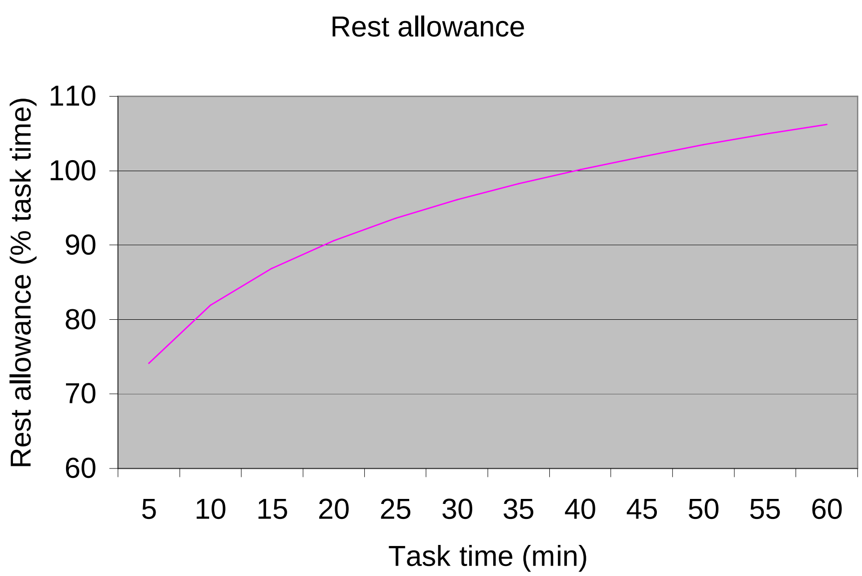

Figure 2 Variation of rest allowance in relation to task time

Table 4: Total cardiac cost of work, physiological cost of work and classification of work load of weeding activity. N 6

Physiological Parameters:	Sawing Activity
Cardiac Cost of Work (beats/min)	68.90
Cardiac Cost of Recovery (beats/min)	25.09
Rate of Exertion	Heavy workload

The specific task of sawing from top of the log (138.85±9.5 bt. min−1) as compared to sawing while standing in a pit beneath the log 123±4.7, imposed the most severe workloads on the sawyers. Similar trend was observed even when the individual subject's performance was assessed while working as topman or pitman (Figure 2). Although the saw rips the log on downward stroke, it is evident that more force is required to pull the saw upwards which is done by the topman. The topman does a harder task to pull weight of saw upwards through the kerfs.

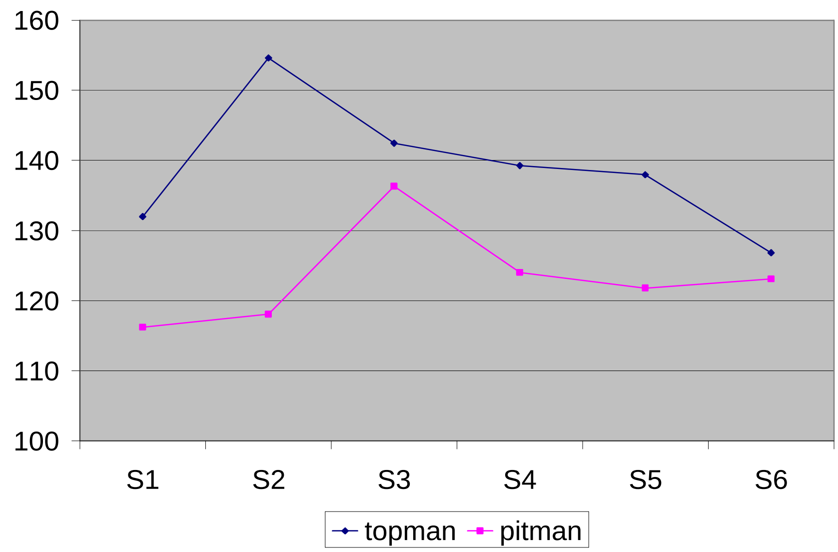

Figure 3: Working heart rate of subjects when sawing from the top of the log (topman) and below the log (pitman)

CONCLUSION

The assessment of the ergonomic cost of pitsawing on the basis of heart rate and energy expenditure excretion showed that ergonomic cost while performing the sawing activities was high. The study concludes that the activity is heavy and induces fatigue in some or other way to the sawyers. Therefore the suitable low cost, improved technologies should be developed/introduced to minimize reduce the hard physical effort, arduousness and harmfulness of the work

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