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# THE PHYSIOLOGICAL COST OF WORK — AN ERGONOMICS APPROACH —

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*Two papers presented during the 1984 LIRA "Human Resources in Logging" seminar (Ref. 7, 15) referred to the high work loadings that typify logging work. Both papers referred to studies conducted overseas and at this stage no work quantifying the work load of loggers in New Zealand has been undertaken.*

*Numerous published research results have suggested that techniques developed during a project have significant "ergonomic" advantages. Two examples of such claims are as follows. As a result of the Swedfor Consultancy in 1980 (Ref. 13), a strong recommendation for the use of lighter saws was made. Two reasons given for such a recommendation were :*

*"the work is safer*
*the work load is less fatiguing"*

*No suggestion was made as to how the second statement could be quantified other than subjective assessment by the operator. The second example (Ref. 6) involves the use of a portable winch to pull skidder/tractor mainrope up short steep slopes. Within the conclusions the author noted that :*

*"The portable winch has the potential to eliminate the physical demands involved in manually pulling machine mainrope and strops uphill. This low cost, lightweight easily carried unit can make the logging of short steep slopes (up to 70 m in length) economically and ergonomically viable."*

*While the economies can be readily quantified, we have had to again rely on subjective assessment as to the elimination of the physical demands.*

*The intention of this Report is to introduce the concept of measuring work load.*

## INTRODUCTION

Work Measurement, as practiced by Work Study practitioners, is widely used in the logging industry to measure performance and to set work standards. The Work Measurement approach to labour utilisation is important in evaluating a system, in spite of its methodological shortcomings (e.g. Ref. 10) but is unsuitable for measures of direct performance. Work measurement is not suitable since it gives "no indication of the cost to the operator of maintaining the overt level of performance (Ref. 4). This can only be achieved by measuring the physiological capacity of a worker to carry out a task; and involves the use of methods and techniques developed by ergonomists over the last forty years.

According to the New Zealand Ergonomics Society, "Ergonomics is a technology that seeks to improve mental and physical well-being by optimising the function of human-machine- environmental systems".

The use of ergonomics is widely used in Europe and most European countries have passed legislation requiring organisations to use ergonomic principles in the work place.

This paper will focus on one aspect of ergonomics - the physiological cost of work - by looking at the methodology used and the way the results are analysed.

Most studies of man performing physical work involve the measurement of one or more of the following main parameters; oxygen consumption, heart rate, cardiac output and minute ventilation (Ref. 14). Of these, the two most extensively used are oxygen consumption and heart rate.

## OXYGEN CONSUMPTION

Each person's capacity for heavy work (such as logging) is dependent on energy consumption and cardiac capacity. Because energy consumption is related to oxygen consumed, this latter quantity is used to give an indirect measure of the energy expended.

The measurement of oxygen consumption is achieved by attaching to the subject a mask with valves that direct the exhaled air either to a bag or a gas meter. The oxygen consumed is then determined. This value is then compared to the maximum oxygen consumption of the worker and an index is thus obtained. The maximum oxygen consumption for a worker is determined by means of a standard test using, typically, either a bicycle ergonometer, or a step test.

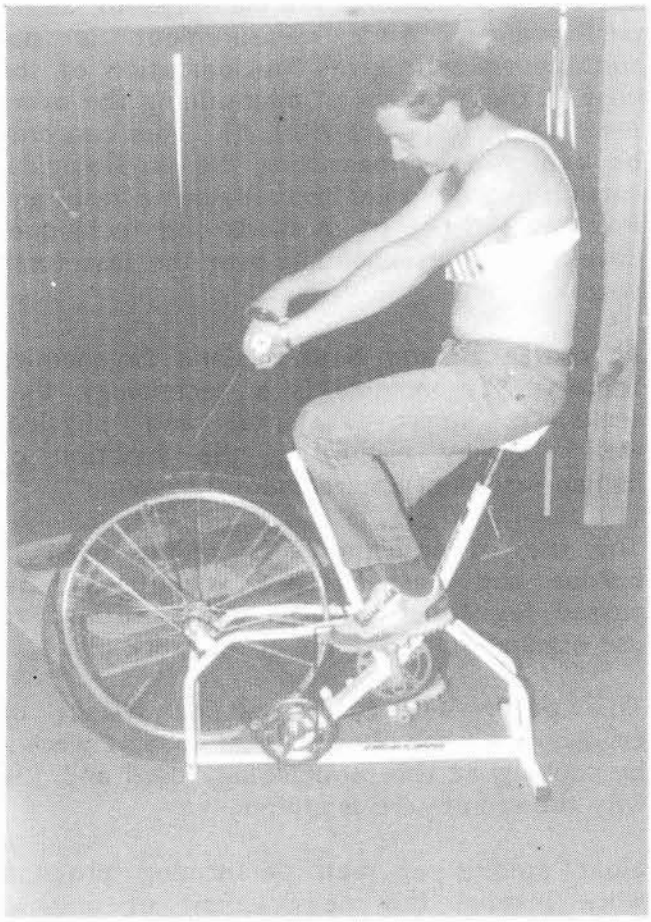

*Figure 1 - Establishing base-line pulse rate*

The index is :

$$\frac{VO_2 \times 100}{VO_2 \text{ max}}$$

($VO_2$ = volume of oxygen used doing measured task)

Most researchers agree that this index should be in the region of 33% (Ref. 9) although some have suggested a value as high as 50% (Ref. 2). Once the $VO_2$ value for various tasks has been established, assigning personnel to various tasks, based on their $VO_2$ max, not only becomes a straightforward operation but, above all, ensures effective use of operators without the danger of health and performance deterioration due to over exertion.

## HEART RATE

Measuring oxygen consumption presents problems of validity, reliability and practicability (Ref. 16). For example, the measurement of oxygen consumption in the work place involves the use of a mask that may impede the performance of a task and become very uncomfortable if the work is being carried out in hot environments. Also, oxygen consumption only measures energy expenditure rather than total strain.

In contrast to oxygen consumption, heart rate is easily measured in the work place. Small heart rate monitors have been developed that can monitor heart rate for long periods without interfering with the subject's work. In addition, as long ago as 1957, Le Blanc (Ref. 8) reported that the main factors in physical work are the supply of oxygen to the muscles and the dissipation of heat produced. Both depend on "the ability of the circulatory system to adapt itself to body requirements and since heart rate is directly affected by these circulatory changes" the use of heart rate as a measure of total load is to be preferred. More recently, Rodahl et al (Ref. 12) used heart rate monitoring continuously and found that it represented stress in the job better than any other parameter that involves samples.

They suggested that this was because the nature of work is intermittent and therefore only continuous recording would reflect the work situation accurately. They conclude that this approach provides a very powerful tool, especially when it is tied in to direct observations. Rodahl et al also used their readings to obtain estimates of oxygen uptake. They found the conversion "adequate for all practical purposes of a field investigation".

So heart rate is easily measured in the work place and can be used to estimate oxygen consumption. The question that now arises is what are the acceptable limits of heart rate magnitude? Some research workers conclude that the overall circulatory strain, as measured by total pulse, should not exceed 110 beats per minute (e.g. Ref. 1, 5) while others (e.g. Ref. 3, 11) have suggested a maximum of 130 beats per minute and 140-150 beats per minute (Ref. 17). The main disadvantage of this approach, which is still used in the Swedish logging industry, is not so much the varying values in heart rates given as the maximum allowable, but that it does not take individual differences into consideration as far as "resting" or "sleeping pulse" is concerned.

To overcome these difficulties, a number of indices have been developed. Together with the index for energy expenditure, these give a clear indication of the work load of tasks. The main ones are :

(1) mean relative heart rate at work =

$$\frac{fcw - fcs \times 100}{fcmax - fcs}$$

(2) ratio $\frac{fcw}{fcs}$

(3) and "the 50% level" =

$$fcr + \frac{fcmax - fcr}{2}$$

(it has been established that a worker's heart rate during work should not exceed his 50% level)

where :

fcw = mean heart rate during work

fcs = mean heart rate during sleep

fcr = mean heart rate during rest

fcmax = maximum heart rate

In addition, by means of heart rate partitioning, the effects of work load and the thermal environment can be evaluated (Ref. 16).

## CONCLUSION

At present, New Zealand workers are generally assigned tasks and levels of activity based on either or both of the following criteria. Firstly, work loads may be set according to what the management may impose on the workforce (or what the worker (or trade union) considers reasonable). Secondly, they are based on performance standards (which may be the result of a work study investigation). The standards so set are usually accompanied by claims of dubious scientific validity.

Ergonomists have attempted to provide a more rational basis for the establishment of work loads. The experience in other countries suggests that this is a valid approach resulting in a healthier workforce (both mentally and physically) and improved effectiveness. The expenditure involved in using this approach is minimal.

LIRA, in conjunction with staff from Massey University and The Disabilities Resource Centre in Palmerston North, is currently evaluating/developing a portable heart rate monitor. Such equipment will enable us to record loggers heart rate during work and, using techniques discussed in this report, determine work loadings placed on workers.

The intention of such data recording is, for example, to compare the work load imposed on a breakerout working in heavy slash with one working in wood prepared using the organised felling technique. It is also envisaged that the equipment would be used to compare work loads using different size chainsaws and bars. Such research will enable more confident assessment of the ergonomic benefits of various developed techniques.

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