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PHYSIOLOGICAL WORKLOAD OF FOREST WORK

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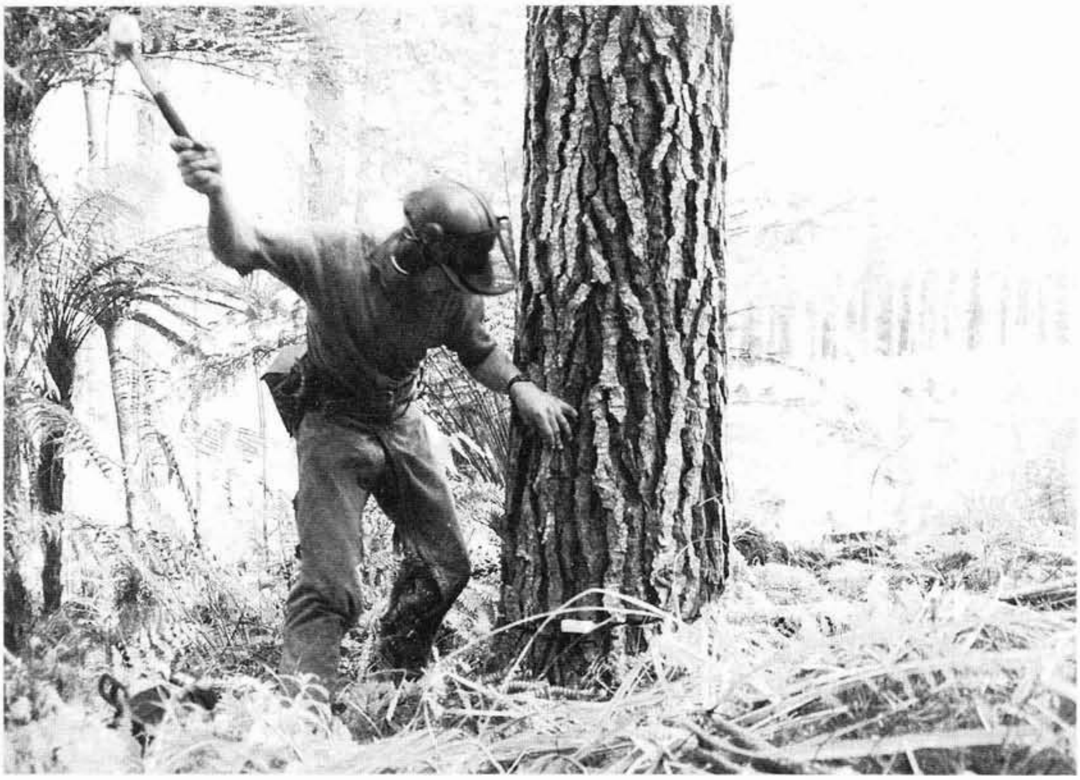

Figure 1 - Driving wedges is a high physiological workload task

ABSTRACT

The concepts of work capacity and physiological workload are explained and a summary of studies undertaken by LIRO to investigate the physiological workload of forestry and logging tasks is presented.

INTRODUCTION

The objectives of this report are to explain the concepts of work capacity and physiological workload and to show how they relate to the New Zealand forest worker.

Many of the tasks in logging and forestry work are among the most physically demanding of full time occupations (Åstrand & Rodahl, 1977). Considerable work has been undertaken by the Scandinavians in this field but their data cannot be used to estimate the workload of New Zealand forest workers because the working conditions are quite different. The trees in New Zealand are larger with greater diameter branches, the terrain is often steeper and the climate warmer. LIRO has been measuring how physically demanding forest work is under New Zealand conditions in an attempt to improve the working conditions of forest workers. New techniques or items of equipment can be tested to determine if they alter the physiological workload of the forest worker. If a new technique or item of equipment does impose a greater physiological load, it will likely not be used and further modifications and developments would be necessary for their successful introduction.

PHYSIOLOGICAL WORKLOAD

Physiological workload is a measure of how physically demanding a job is. If your muscles ache, you are out of breath and your heart is racing when you work you are experiencing a very high physiological workload. The body is like a diesel or petrol engine, it needs oxygen to burn its fuel. Normally there is sufficient fuel (food broken down to sugars), so the power of the "engine", depends on how much oxygen the muscles are getting. That is why you gasp for air when working hard. To work hard, enough oxygen must get to the muscles so they can burn the sugar and create energy to do work. When the muscles start to burn "rich", because they are starved of oxygen, lactic acid builds up and causes the muscles to ache. This is anaerobic respiration and the only remedy is rest until the oxygen concentration in the muscles builds up again and aerobic respiration resumes.

Physiological workload can be expressed in units of energy. As an example, a study of fallers in Finland found that they consumed 13 MJ (3100 kilocalories, commonly called "calories") of energy during the five hours they actually felled and trimmed trees. They then burned another 7 MJ (1670 calories) of energy in non-work time (Kukkonen-Harjula, 1984). For 24 hours they needed 4770 calories of energy. If fallers did not eat at least this much energy each day, they would start to lose weight as fat and muscle was broken down for energy.

WORK CAPACITY

Some people can cope with physically demanding work better than others. This is because they can get more oxygen to their muscles and they can work harder and longer before lactic acid builds up. This difference between people is called their work capacity. Someone with a high work capacity could fell and trim trees all day without ever getting out of breath. Yet another logger of the same height, weight and age doing the same work but with a lower work capacity would be exhausted. High work capacity can be due to genetic factors such as a bigger, stronger heart which can pump more blood from the lungs to the muscles. Training can increase work capacity, and work capacity decreases with increased age. Work capacity can be estimated on a special stationary cycle (known as a cycle ergometer). People being tested cycle against a range of increasing loads and their power output is measured. At the same time their heart rate is recorded (Figure 2). At the same heart rate Logger 1 has a higher power output than Logger 2.

People with a high work capacity can generate more power with a lower heart rate and they will be breathing less heavily. There is a link between work capacity and productivity. For example, a Swedish study (Hansson, 1965 cited by Åstrand & Rodahl, 1977) reported that very high earning loggers working a piece-rate system had significantly higher work capacities compared with average earners.

One controversial question that has never been investigated is work capacity and the

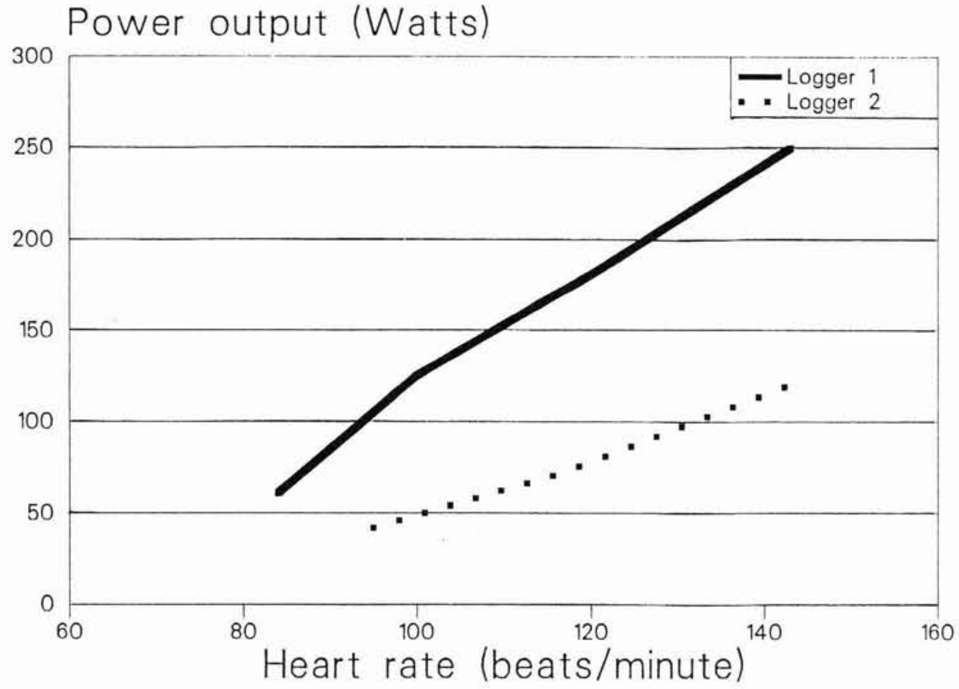

Figure 2 - Comparison of heart rate and power output of high (Logger 1) and average (Logger 2) work capacity individuals

risk of accident. If not able to work at their own lower work rate, people of low work capacity will be more exhausted and may be prone to making dangerous mistakes

MEASUREMENT OF PHYSIOLOGICAL WORKLOAD

LIRO researchers measure physiological workload of forest workers in the field by recording the worker's heart rate throughout the day. The heart rate is recorded every 15 seconds on to a belt mounted receiver. At the same time, an observer records the worker's activity every 15 seconds (for example, Pruner: walk, prune; Faller: scarf, backcut, remove sloven, trim, refuel, etc.) on a portable field computer. The heart rate record and the activity record are then matched on a computer spreadsheet programme and the average heart rate for each activity is calculated and estimates of workload are determined.

The following scale has been proposed by Rodahl (1989) to give estimates of workload from heart rate:

Heart rate (beats/minute)	Physiological workload
less than 90	Light
90 - 110	Moderate
110 - 130	Heavy
130 - 150	Very heavy
150 - 170	Extremely heavy

Workload can also be estimated by measuring sweat rate. This is the volume of sweat lost over, say, an eight hour working day. Heavy work in hot conditions can result in a loss of 400 ml/hour (Apud et al., 1989) so the worker must drink almost four litres (since there will be some water in food) to replace what has been lost. Dehydration will reduce work capacity and so decrease productivity.

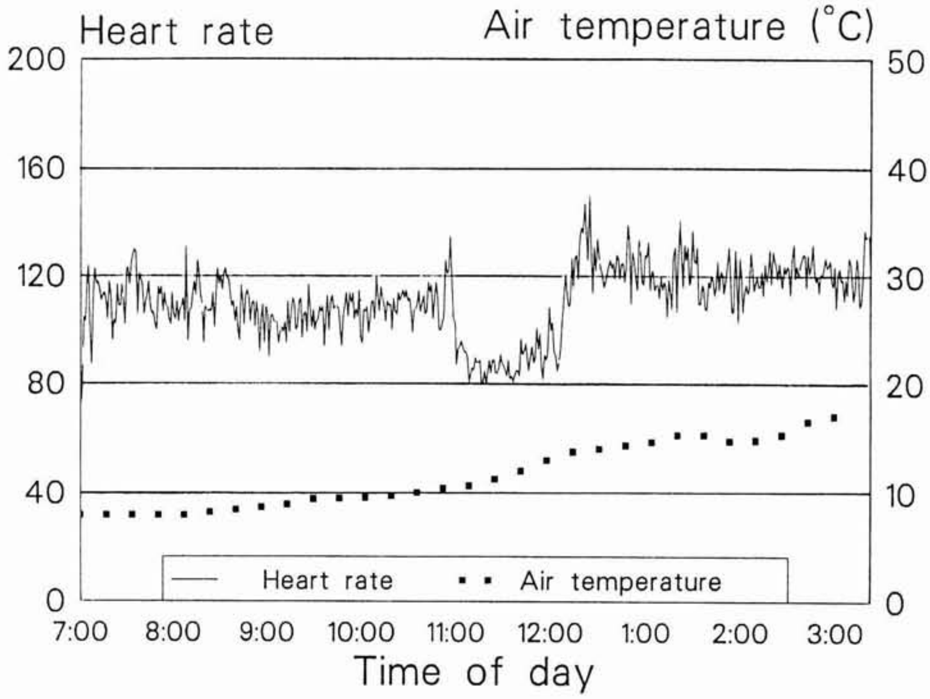

Figure 3 - Heart rate of 26 year old manual pruner during the working day. Air temperature (°C) was recorded at the work site

EFFECT OF THE ENVIRONMENT ON PHYSIOLOGICAL WORKLOAD

The environmental conditions on logging and forestry operations are frequently less than ideal. The work (planting, pruning, felling, delimbing, breaking out) is often carried out on a slope and in dense undergrowth. Weather and ground conditions are frequently unpleasant, hot and humid or wet and slippery. In situations such as this the physiological workload can be very high.

Factors which increase physiological workload are:

- terrain, having to pull strops up a slope
- tools, using a heavy saw
- working in hot conditions, on landing with no shade
- working in humid conditions, pruning in thick undergrowth
- work method, pruning at the top of a ladder
- pace of work, tractor hauling close to the landing.

A plot of a manual pruner's heart rate against time of day (Figure 3) indicates that as air temperature at the work site increases (from 8°C to 17°C) so does heart rate.

Many studies have demonstrated that people doing heavy manual work at their own pace will work comfortably at an average of 40% of their cardiovascular load (CVL) over the whole working day.

A "rule of thumb" estimate of CVL can be made from heart rate and age:

resting heart rate = 0% CVL
220 beats/minute - age = 100% CVL

For example, a 35 year old faller with a resting heart rate of 65 beats/minute will have a heart rate of 113 beats/minute at 40% CVL.

Average heart rate of the faller increased with increasing air temperature (Table 1). His productivity also decreased from 7 to 4.6 stems/hour as the workload increased with increasing air temperature and fatigue.

Table 1 - Average heart rate (± SD) related to air temperature and productivity for 35 year old faller over the working day

	Run 1 7:00am-10:30am	Run 2 11:00am-1:30pm	Run 3 2:00pm-3:30pm
Working heart rate	113 ± 7	141 ± 10	146 ± 7
Refuel saw and sharpen chain heart rate	96 ± 10	126 ± 10	125 ± 7
Air temperature (°C)	15.1 ± 4.4	21.6 ± 1.4	25.8 ± 1.1
Productivity (stems/hour)	7.0	6.8	4.6

Table 2 - Average (± SD) and range of heart rates for workers engaged in forestry and logging tasks

Task	Planting (flat ground)	Pruning 1st lift	Pruning 2nd lift	Motor manual felling & delimbing	Mechanised felling	Breaking out	Log making
Heart rate ± SD	153 ± 18	114 ± 9	126 ± 8	127 ± 18	70 ± 4	115 ± 4	110 ± 12
Range	95 - 188	76 - 126	76 - 149	80 - 165	62 - 99	79 - 150	80 - 161
Work rate (trees/hr)	144	18	26	6	70	10 drags/hr	22
% CVL	68	34	43	52	10	37	31
Age	30	20	20	35	42	19	33
Resting heart rate	75	70	70	65	58	65	75
Reference	Trewin & Kirk, 1992	Hartsough & Parker, 1993 Kirk & Parker, 1994	Hartsough & Parker, 1993	Gaskin & Guild, 1989 Gaskin, 1990 Kirk & Parker, 1992 Parker, 1992		Kirk & Parker, 1993	Parker *et al.*, 1993

PHYSIOLOGICAL WORKLOAD OF SOME FOREST TASKS

Heart rate information presented in Table 2 is drawn from LIRO studies of New Zealand forest workers under normal production conditions. However caution must be used when trying to compare the workload of each task. Workload (measured as heart rate) is influenced by work rate, environmental and operational factors mentioned earlier and age of the worker. The "% of CVL" value gives an indication of the exertion experienced by the worker under the conditions prevailing at the time of the study.

Results indicate that planting trees can be extremely physically demanding. The ground had been ripped and mounded so there were few interruptions to slow the planter down and allow his heart rate to recover. The planter would not be able to sustain working at 68% of his CVL for very long. The limit for continuous work is 40% of CVL averaged over the whole day. On steeper country and in heavy slash, the work rate of the planter was considerably reduced, resulting in a lower physiological workload.

Workload of second lift pruning (Douglas fir) was greater than first lift pruning because of the higher work rate, the extra effort needed to hold on to the tree with one leg and the greater proportion of pruning above the head. Second lift pruners can prune more trees per hour because they do not have to spend time selecting the next tree. Selection time does, however, allow the heart rate to recover.

Motor manual felling and delimbing is a very high workload task, particularly delimbing with a heavy chainsaw. In comparison, operating a feller-director (Hultdins F850 head on a Cat EL200B base) in clearfell radiata at a considerably greater work rate was a light physiological workload task.

Breaking out can be classified as a heavy workload task but has periods of very heavy workload where heart rate is above 130 beats per minute, while strops and butt rigging are pulled to the drag and during rapid movement to a safe location. Heart rate has time to fall during the in-haul and out-haul phases when the breakerout is planning his next drag. This particular breakerout was working very close to 40% of his CVL and would have difficulty working at a faster rate for a sustained period of time.

Log making exhibited a workload which could be classified as moderate to heavy because the logmaker used a chainsaw on the landing. Logmakers who only assessed, measured and marked logs would have a lower workload. The range in heart rate (75 to 161 beats per minute) is due to breaks to sharpen the saw and wait for drags to arrive on the skid and running across the skid to unhook drags.

THE FUTURE

Very carefully controlled studies looking at the change in workload of forest workers using different types of equipment and techniques can be undertaken. For example, the use of pole mounted chainsaws for pruning, smaller chainsaws for delimbing, chainsaws designed specifically for delimbing, rotation of jobs within the crew on very hot days, the use of shade on the skid and fluid intake effects. The Armed Forces have done this with much of their equipment. They have found that a 100 g increase in the weight of a pair of boots increases workload of walking by 1% (Legg & Mahanty, 1986). So, give a man boots 100 g heavier and he will probably give you 1% lower productivity to keep his workload constant.

CONCLUSIONS

Workload can be estimated in the field from the measurement of heart rate, and work capacity of an individual can be estimated by cycle ergometry. Those people with a greater work capacity have the potential for greater productivity. However, environmental conditions such as weather and terrain have a large influence on workload and subsequent productivity. Therefore managers of forest workers (supervisors and contractors) must be aware of the need for, and benefits of, rest breaks under conditions of high workload existing in most logging and forestry operations in New Zealand.

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