Session 5
Paper (a)

WORKLOAD OF LOGGERS IN DIFFICULT TERRAIN

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INTRODUCTION

The objective of this paper is to explain the concepts of work capacity and physiological workload and show how they can be used by the logging industry. The subject of this seminar "Logging in Difficult Terrain" is very appropriate when discussing physiological workload because when a logger is on difficult terrain (eg. felling and trimming on a steep slope up to his knees in slippery slash) his physiological workload can be extremely high.

Logging is one of the most physically demanding fulltime occupations (Åstrand & Rodahl, 1977). Scandinavian data cannot be used to estimate the workload of New Zealand loggers. The trees in New Zealand are larger with more big branches, the terrain is often steeper, it is hotter in summer and loggers in New Zealand use larger chainsaws. So we need to measure work load under New Zealand conditions. LIRO has been measuring how physically demanding logging is under New Zealand conditions. This work is being done to attempt to improve the working conditions of loggers through improved method or equipment developments. If any new techniques or items of equipment are developed they can be tested to see if they affect the physiological workload of the logger. If a new technique or item of equipment makes the job harder it will likely not be used and further modifications and developments would be necessary for 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 it's 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 13MJ (3100 kilocalories, commonly called "calories") of energy during the 5 hours they actually cut down and trimmed trees. They then burned another 7MJ (1670 calories) of energy in non-work time (Kukkonen-Harjula, 1984).

So 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. Also training can increase work capacity, and work capacity decreases with increased age. Falling the first week back after a long break is tiring because fitness has been lost. Work capacity can be estimated on a special stationary cycle (known as a cycle ergometer). The person being tested cycles against a range of increasing loads and their power output is measured. At the same time their heart rate is recorded (Fig.1). At the same heart rate Logger 1 has a higher power output than Logger 2.

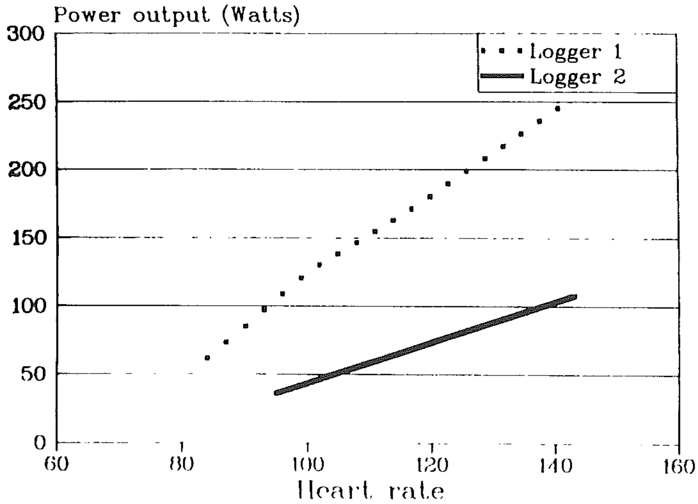

Figure 1. Comparison of heart rate and power output of high (Logger 1) and normal (Logger 2) work capacity individuals.

A person 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 risk of accident. A person of low work capacity will be more exhausted and may be prone to making dangerous mistakes if not able to work at his own lower work rate.

MEASUREMENT OF PHYSIOLOGICAL WORKLOAD

LIRO researchers measure physiological workload of loggers in the field by recording the loggers heart rate throughout the day. The heart rate is recorded every 15 seconds onto a belt mounted receiver. At the same time an observer using the activity sampling technique records the loggers activity every 15 seconds (eg. scarf, backcut, remove sloven, trim, refuel, etc) on a portable field computer. The heart rate record and the activity record are then matched up 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

Heart rate is affected by emotional state but if a person is doing physical work and their heart rate is above 110 then only the effect of physical work on heart rate is being measured.

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 500 ml/hour (Apud *et al.*, 1989) so the worker must drink almost 4 litres (since there will be some water in food) to replace what has been lost. Dehydration will reduce work capacity and so decrease productivity.

EFFECT OF THE ENVIRONMENT ON PHYSIOLOGICAL WORKLOAD

Felling and trimming in a good quality stand, (flat with no undergrowth, big trees with few limbs) on a cool, dry day is every fallers dream. But reality is rarely like that. More often, felling and trimming is done on a slope, the under growth is dense, the trees lean the wrong way and have lots of branches. Often conditions are wet and slippery or hot and humid. In situations such as this the physiological workload can be very high.

Factors with increase physiological workload are:

- terrain, eg. having to trim on a slope
- carrying a heavy saw
- working in hot conditions
- working in humid conditions

Many studies have demonstrated that at person 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 - 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. A plot of the distribution of heart rates of a 35 year old faller indicates his heart rate is well above his comfortable limit of approximately 113 beats/minute (Fig. 2).

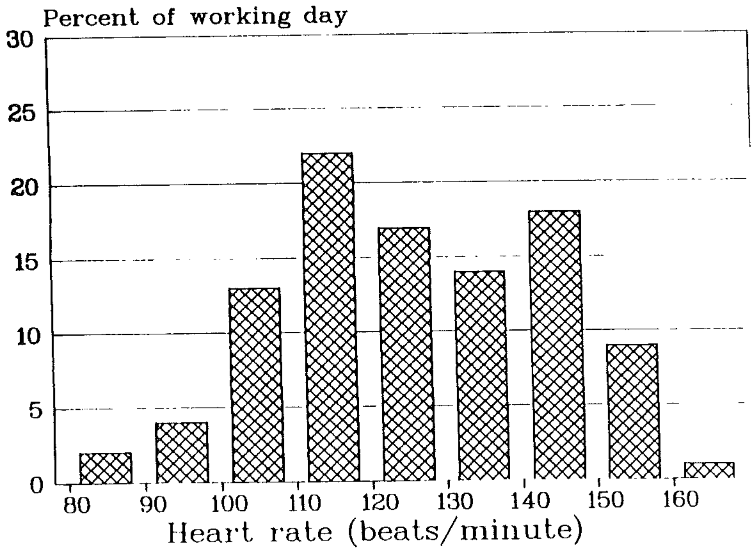

Figure 2. Working heart rate distribution (meal breaks excluded) of 35 year old faller.

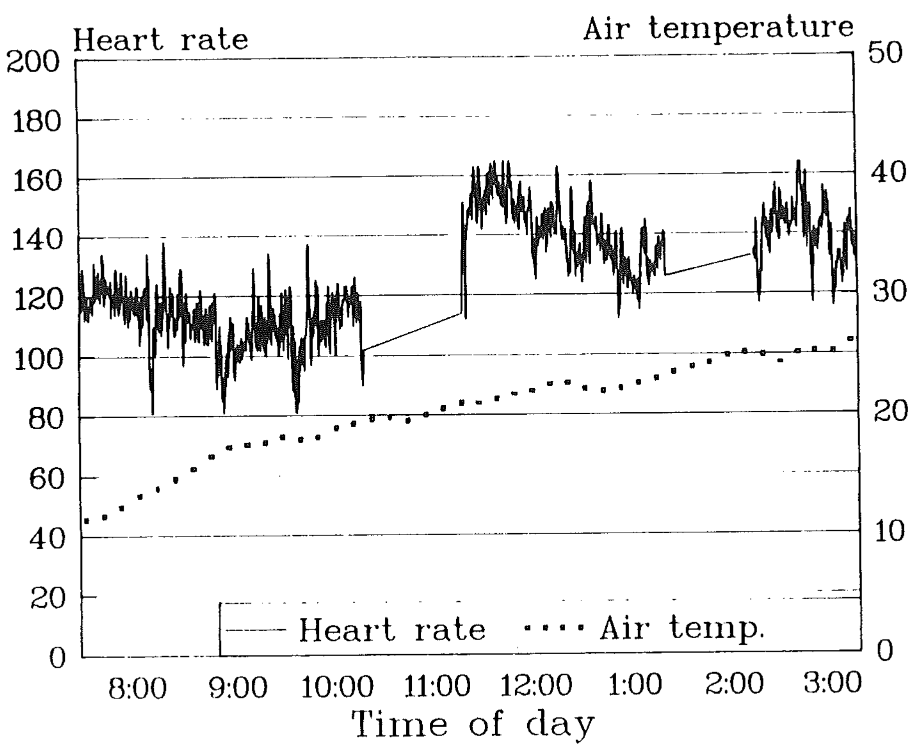

Figure 3. Heart rate of 35 year old faller during the working day. His heart rate was not recorded during meal breaks. Air temperature (°C) was recorded at the felling face.

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

Logging task	Run 1 7:00am-10:30am	Run 2 11:00am-1:30pm	Run 3 2:00pm-3:30pm
Walk and inspect	114 ± 10	137 ± 8	133 ± 10
Clear around butt	114 ± 8	142 ± 10	141 ± 9
Scarf	113 ± 9	143 ± 11	142 ± 8
Back cut	110 ± 8	140 ± 11	139 ± 6
Cut off sloven	110 ± 8	138 ± 12	136 ± 8
Delimb standing beside stem	112 ± 8	139 ± 12	146 ± 6
Delimb standing on stem	113 ± 7	141 ± 10	146 ± 7
Refuel saw and sharpen chain	96 ± 11	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

The plot of fallers heart rate against time of day (Fig.3) indicates that as air temperature on the felling face increases (from 8°C to 27°C) so does heart rate. Gaps in the heart rate record indicate meal breaks. A breakdown of faller activity into individual tasks (Table 1.) indicates how average heart rate for each task of the faller increased with increasing air temperature. His productivity also decreased from 7 to 4.6 stems/hour as the workload got greater with increasing air temperature and fatigue.

New Zealand evaluation of delimbing beside the stem and delimbing while standing on top of the stem reported no difference in average heart rate for the two methods (Gaskin, 1990) indicating workload was the same. The study however did reveal that delimbing from the side significantly reduced loading on the loggers spine.

THE FUTURE

Very carefully controlled studies looking at the change in workload of loggers using particular types of equipment and techniques can be done. For example, investigation of chaps vs trousers, new types of rainwear, rotation of jobs within the crew on very hot days, the spacing of meal breaks through the day, physical fitness of loggers, diet and fluid intake effects and using smaller saws. The Armed Forces have done this with much of their equipment. They have found that a 100g increase in the weight of a pair of boots increases workload of walking by 1% (Legg & Mahanty, 1986). So, give a man boots 100g heavier and he will probably give you 1% lower productivity to keep his workload constant.

CONCLUSION

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 to greater productivity. However environmental conditions such as weather and terrain have a large influence on workload and subsequently productivity. Therefore managers of loggers (supervisors and contractors) must be aware of the need for rest breaks under conditions of high workload.

REFERENCES

Apud, E.; Bostrand, L.; Mobbs, I.D.; Strehlke, B. Guide-lines On Ergonomic Study in Forestry, 1989. ILO, Geneva.

Åstrand, P.O.; Rodahl, K. 1977 Textbook of Work Physiology McGraw-Hill, New York.

Gaskin, J.E. 1990 An ergonomic evaluation of two motor-manual delimbing techniques International Journal of Industrial Ergonomics 5, 211-218.

Hansson, J.-E. 1965 The relationships between individual characteristics of the worker and output of work in logging operations In Textbook of Work Physiology, P.O. Åstrand, K. Rodahl.

Kukkonen-Harjula, K. 1984 Oxygen consumption of lumberjacks in logging with a power-saw. Ergonomics, 27, 59-65.

Legg, S.J.; Mahanty, A. 1986 Energy cost of backpacking in heavy boots. Ergonomics, 29, 433-438.