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FATIGUE LEVELS IN MOTOR-MANUAL TREE FELLING AND DELIMBING OPERATIONS

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INTRODUCTION

Heart rate measurements and questionnaires were successfully used to determine the impact of physical and mental fatigue on six full time clearfell fallers. Both methods of data collection were able to be used quickly and easily with minimal disruption to the fallers' normal working day. Both measures generated information which could be used to determine the impact of fatigue on worker safety, physical strain and productivity.

CONCLUSIONS

- Heart rate measurements and questionnaires are an effective means for determining physiological strain of subjects in field situations.
- All physiological measures placed the tasks of felling and delimbing in the moderate to heavy workload categories.
- All fallers felt significantly more physically fatigued and uncomfortable as the day progressed.
- None of the fallers appeared to suffer from mental fatigue.
- Moderate to severe body part discomfort of the lower back region was recorded for all of the fallers.
- Average hourly production decreased from 13 m^3 in the morning to 11 m^3 in the afternoon.
- An average daily production of 96 m^3 per faller generated an average hazard rate of 15 hazards per 100 stems.
- The felling phase accounted for 28% of the hazards, with the remaining 72% occurring during trimming.

RECOMMENDATIONS

- Ensure optimum physical and mental performance of the worker by maintaining an adequate intake of fluid and food throughout the day.
- Use rest breaks to reduce the impacts of physical and mental fatigue.
- Mechanise the trimming and felling phases of the operation wherever possible.
- Ensure workers are trained in the use of alternative trimming techniques such as the Swedfor trimming method, and are aware of the physical and musculoskeletal benefits of using such a technique.

INTRODUCTION

New Zealand's forest industry requires a large amount of manual labour. This trend will continue to be the case for the foreseeable future due to a relatively large proportion of the forest resource being located on steep and difficult terrain.

Manual forestry work has been categorised by researchers worldwide as a job requiring moderate to heavy physical workloads (Fibiger and Henderson, 1984). The work is often undertaken in unpleasant conditions and in close proximity to potentially dangerous equipment and situations. Physical and mental fatigue routinely affect many forest workers throughout the working day. Fatigue reduces performance, lowers productivity and increases unsafe behaviour as workers begin taking dangerous short cuts which require less physical effort.

A large number of factors need to be constantly monitored, observed and corrective action taken while working in forest harvesting operations. If any one of these factors are mis-read or neglected, the result for the forest worker can be serious injury or death.

STUDY OBJECTIVE

The objective of this study was to establish whether heart rate indices and subjective questionnaires could be used to determine the impact of physical and mental fatigue on six full time clearfell fallers under normal operational conditions.

ACKNOWLEDGMENTS

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METHOD

Subjects

Six full time professional fallers working in clearfell logging operations were each observed continuously for five complete working days.

Physiological Measures

Working heart rate, aerobic capacity and energy expenditure were determined for each faller and applied to heart rate indices, in order to determine the level of physical strain experienced by the fallers.

Production

Continuous time study was undertaken to determine the percent of the working day spent on each task. The volume of timber felled per hour and per day by each faller was derived by multiplying the number of trees felled by the average stem volume in cubic metres (m^3). Ground slope was measured and undergrowth hindrance estimated for each felling face.

Safety

Hazardous felling and delimbing situations and techniques as defined by Östberg (1980), and later modified by Parker and Kirk (1993), were used to determine hazard type, ratio and frequency of occurrence.

Temperature

The temperature at each work site was recorded throughout each working day by a portable automatic weather station placed as close as practical to the faller. This information was then used to calculate the relative humidity and wet bulb globe temperature (wbgt) for each site.

Subjective Measures

Subjective comfort and sensation assessments were measured using standard questionnaires at one hour intervals throughout the working day. These measured, perceived thermal comfort and sensation, skin wettedness and thermal regulation. Self-assessed fatigue, body part discomfort and mental fatigue were also measured at one hourly intervals, as well as at the start and end of the working day.

RESULTS AND DISCUSSION

Physiological Measures

All physiological measures placed the tasks of felling and delimbing in the moderate to heavy workload category (Åstrand and Rodahl,1986). While felling and delimbing working oxygen consumption was on average 1.5 litres per minute ($l.min^{-1}$), mean working heart rate was 107 beats per minute ($bt.min^{-1}$) and mean energy expenditure was 7.4 kilo calories per minute ($kcal.min^{-1}$). The mean heart rate for each task and the percentage of the working day spent undertaking each task are shown in Figure 1.

Production

Average hourly production decreased from 13 m^3 in the morning to 11 m^3 in the afternoon. The fallers spent most of their working time undertaking the tasks of trimming (36%), felling (18%) and selecting the next tree to fell (7%). The lunch break accounted for 11% of the entire working day.

Figure 1 - Mean heart rate per task and percentage of day undertaking each task

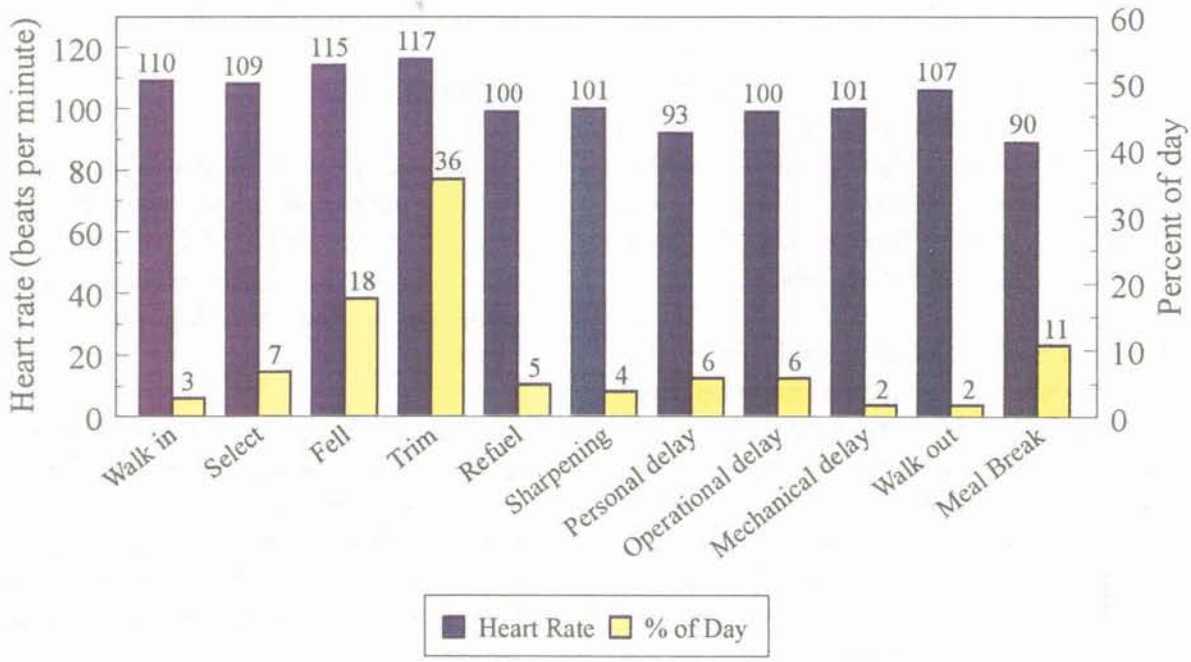
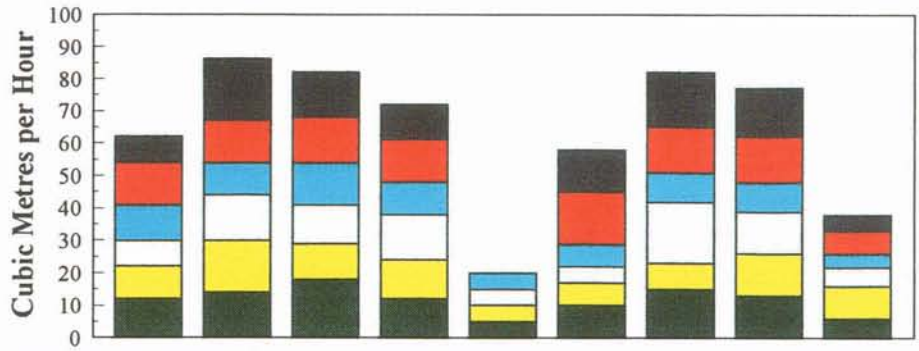


Figure 2 - Average daily and hourly felling production in cubic metres per hour (m^3/hr)



Time	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16
Subject 1	12	14	18	12	5	10	15	13	6
Subject 2	10	16	11	12	5	7	8	13	10
Subject 3	8	14	12	14	5	5	19	13	6
Subject 4	11	10	13	10	5	7	9	9	4
Subject 5	13	13	14	13	0	16	14	14	7
Subject 6	8	19	14	11	0	13	17	15	5

It appears that subjects two, three and four had difficulty returning to full production after the midday break, whereas subjects five and six returned to full production immediately (Figure 2). One explanation for this could be the impact of a 30 minute break (subjects 1 to 4) versus a 60 minute break (subjects 5 to 6).

This meant that subjects five and six had an additional 30 minutes in which to rest and recover from the morning run. The impact of rest breaks on worker productivity has been previously highlighted by other forestry-based research (Fibiger and Henderson, 1984; Golsse and Rickards, 1990; Johnson and Tabor, 1987).

Rest pauses provide periods in which workers are able to gain some relief from the physical and mental strain of the job. Other research (Alluisi and Morgan, 1982), has shown that short rest breaks in machine paced jobs do not reduce output even though less time is worked. The reasons for maintaining productivity with shorter work time can be largely explained by the fact that rest breaks provide relief from boredom, physiological stress, muscle fatigue and cardiac strain. In addition, the longer lunch break allows for more effective digestion of the food eaten during the break. This, in turn, means that more of the energy contained in the food eaten is able to be used by the body.

Terrain

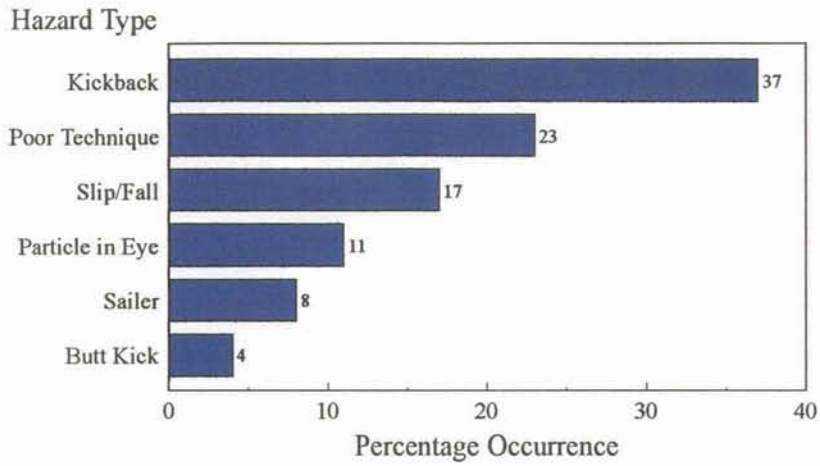
Mean hindrance ratings ranged from 1.3 to 1.5 and mean slope recordings ranged from 1.6° to 2.0°. Terrain, slope and hindrance ratings were considered minimal.

Hazards

An average production per faller of 97 m^3 per day generated on average 15 hazards per 100 stems, with 28% of the hazards occurring in the felling phase, and 72% occurring in the trimming phase of the operation.

The most frequently occurring type of hazard was kickback, followed by poor technique and slip/fall hazards. Poor technique included such things as using the chainsaw one handed or above shoulder height, incorrect placement and/or use of felling cuts (Figure 3).

Figure 3 - Hazard type and percentage occurrence



Only subjects five and six experienced any significant difference between morning and afternoon hazard frequency. Both subjects five and six experienced significantly lower hazard frequencies in the afternoon periods than in the morning periods, while experiencing no decrease in productivity.

Subjective Fatigue Ratings

The physical fatigue aspects appeared to dominate the subjective fatigue ratings with subjects stating that they felt more weary (83%), tense (66%), weaker (100%) and more exhausted (83%) as the day progressed (Figure 4).

Figure 4 - Mean subjective fatigue ratings

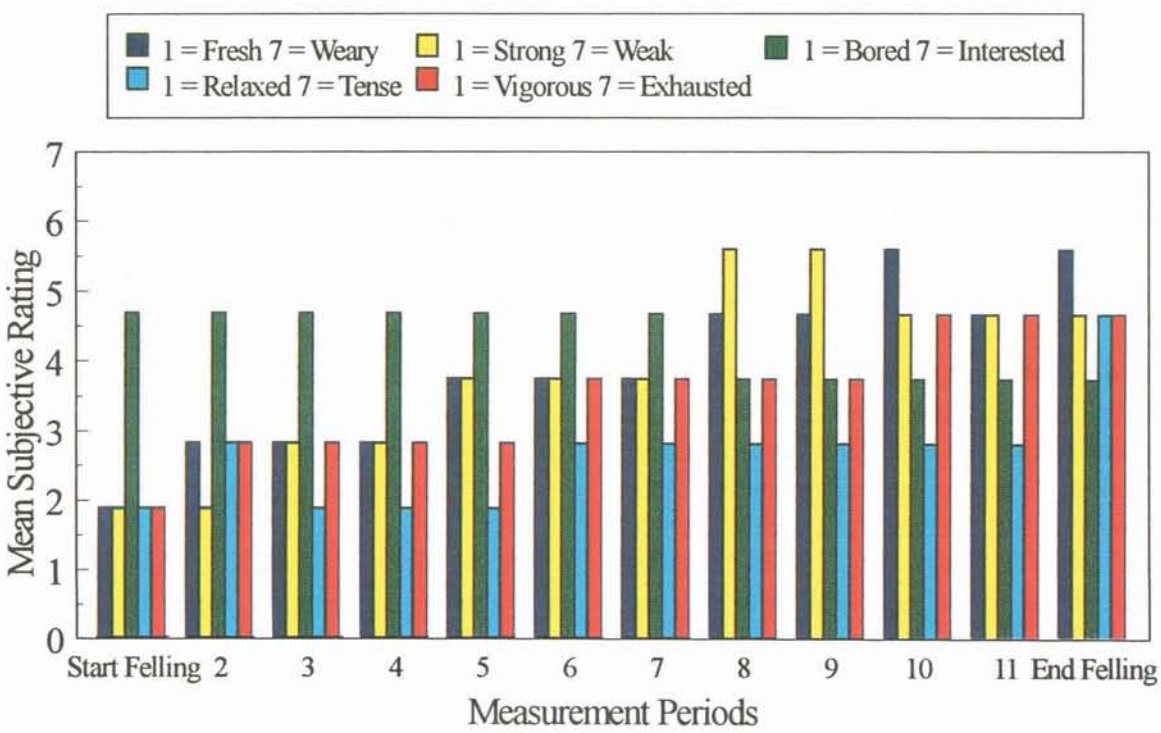


Figure 5 - Faller showing poor delimbing posture

In contrast, the aspects normally associated with mental fatigue appear to have had a lesser effect on the subjects with only (33%) of the subjects stating that they felt more sleepy and bored as the day progressed. This trend appears to be confirmed by the mental fatigue test findings, where mental performance appeared not to suffer any decrease as the day and week progressed.

Body Part Discomfort

All subjects experienced a degree of body part discomfort over a range of body parts. All six subjects recorded moderate to severe discomfort in the mid and lower back regions, with the mean severity rating of four being recorded for 100% of the time (Figure 6). The severity of the discomfort did not change during either the working day or week.

Previous research undertaken in the area of lower back injuries within the logging sector of the New Zealand forest industry (Gaskin, O'Leary and Slappendel, 1988; Gaskin, 1990), clearly documented the bio-mechanical loadings experienced by fallers who chose to delimb while standing on, rather than beside, the stem. Since all of the subjects in the current study tended to favour the "on top" method of delimbing, the recording of such discomfort was not unexpected.

The subjects in this study did not appear to modify their work method according to their body part discomfort. They all continued to delimb by walking along the top of the stem. It appears that the alternative method of delimbing beside the stem (Swedfor), with its associated lower spinal loading, was seen as being too slow and requiring greater physical effort to undertake than the more traditional "on top" delimbing method.

Gaskin (1990) found the same level of resistance to the Swedfor delimbing method with the loggers stating that " it is easier to walk along the top of the log as it gives a relatively clear working platform".

The recording of such high levels of back pain, combined with the apparent lack of acceptance by fallers of the alternative Swedfor delimbing technique, stresses the urgent need to find effective alternatives to current delimbing techniques.

Such an approach is critical as current delimbing techniques offer little hope for the long term health and sustainability of the industry's motor-manual workforce.

Figure 6 - Mean body part discomfort (1 = none 5 = unbearable)

Subjective Comfort Ratings

Two-thirds of the subjects experienced a significant increase in thermal discomfort and sensation as the day progressed. The primary cause was an increase in sweat rate due to increasing temperature.

Mental Fatigue

Mental performance did not show any decrease for any of the subjects as the day or week progressed. None of the six subjects experienced any significant change in either the number of tests attempted or the accuracy of the answers as the day progressed. The lack of any change during the day indicates that little or no mental fatigue occurred.

Ambient Climate

Wet bulb globe temperature (wbgt) ranged from 9ºC to 24ºC. Relative humidity ranged from 61% to 91%.

Previous research has identified a wbgt of 26ºC as being the point at which temperatures impact upon worker productivity and safety (Smith and Rummer, 1988). Temperatures above 26ºC were found to decrease productivity in manual workers by 5%, mechanised operators by 3%, and resulted in a slight increase in unsafe behaviour. Since the temperatures for this study fell below this level, it is considered that they had a minimal affect on the subjects safety and physical performance levels.

CONCLUSIONS

- Heart rate measurements and questionnaires are an effective means for determining physiological strain of subjects in applied field situations.
- All physiological measures placed the tasks of felling and delimbing in the moderate to heavy workload categories.
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