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PROJECT REPORT

AN ERGONOMIC INVESTIGATION OF HAULER BREAKEROUTS

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Project Report

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

Key Findings

- Based on the following methods of estimating workload: relative heart rate at work (%CVL), ratio of working heart rate to resting heart rate, 50% Level, and HR_W /50% Level indices, the mean working heart rate (HR_W) of 106 $bt.min^{-1}$ ± 6.9 (mean ± S.D) placed breaking out in the moderate workload category. The specific tasks of line shifts (120.3 ± 4.8 $bt.min^{-1}$), hooking up drags (118.8 ± 6.6 $bt.min^{-1}$) and uphill travel (126.1 ± 12.9 $bt.min^{-1}$), imposed the most severe workloads on the breaker-outs.

- There was a poor relationship between the breaker-outs perceived rate of exertion, based on a strain intensity from the CR 10 Borg Scale, and the heart rate recorded for the corresponding time period.

- Hazard type and frequency was significantly effected by ambient environmental, logging system and breaker-out experience.

Recommendations

- Two, or more preferably three, rest breaks of an effective length (at least 20 minutes), should be taken at set intervals throughout the working day to allow breaker-outs to rest, eat and replace lost fluids. Such a strategy would reduce the physiological and psycho-physical effects of undertaking heavy physical work.

- Such rest breaks should be taken in an area which affords some form of respite from the environmental stressors of cold and heat.

- When environmental conditions are at extremes of either heat or cold, the operations work procedure should be adapted to reduce the breaker-out's level and/or duration of exposure to such stressors. Shortened days and/or half day job rotations could be applied in such cases.

- Poor and/or lax work practices should not be tolerated. Contractors and senior workers should lead by example to stem the gradual emergence of such dangerous work practices. The safety of the breaker-outs should not be compromised by the drive to maximise crew production.

- Natural hazards should be taken into consideration when formulating harvest plans and production figures amended accordingly to allow for lower, but safer, production during the harvesting of such areas.

INTRODUCTION

The nature of the breaker-out's work often means that moderate to heavy workloads 114-120 bt.min^{-1} (Kirk & Parker 1993a), are undertaken in inhospitable working environments and in close proximity to potentially dangerous equipment and situations. The hazardous nature of the breaker-out's work requires constant vigilance to prevent serious or fatal injuries. A multitude of factors need to be constantly monitored, observed and corrective action taken while breaking-out for clearfell operations. If any one of these factors is mis-read, neglected or incorrectly diagnosed, then the result for the breaker-outs can be serious injury or death.

Most of New Zealand's production forestry based ergonomics research has followed those directions identified by Gaskin in his review of past, present and future ergonomics research within New Zealand's production forestry sector (Gaskin, 1986). This review laid the foundation for much of the subsequent nine years human factors based research within the industry. Consequently there has been extensive work undertaken to identify the physical hazards (Tapp *et al.*,1990; Parker,1991; Parker & Kirk,1993b), accident type and frequency, (Prebble, 1984; Gaskin & Parker, 1992; Parker,1993, Parker, 1994), physiological strain (Vitalis *et al.*,1986; Gaskin,1990; Parker & Kirk,1993a; Kirk & Parker, 1993b; Kirk & Parker, 1994b), biomechanical loadings (Gaskin, 1990; Gaskin et al., 1987; O'Leary, 1988), and the role of personal protective equipment (Prebble, 1981, Kirk,1992; Kirk *et al.*,1992; Kirk,1993; Kirk & Parker, 1994a) associated with forest harvesting operations.

However, the majority of these studies have traditionally utilised only one or two physiological and/or psycho-physiological measures, typically heart rate or self assessed questionnaire, to determine the physiological or mental effort being exerted by the person undertaking the observed task. Studies consisting of complete ergonomic evaluations whose sole purpose is to determine the combined effects of commonly encountered physiological and psycho-physiological stressors on safety, comfort, productivity and physiological strain of forest industry workers have, to date, been relatively rare within New Zealand forest industry's field of ergonomic research.

The most recent work undertaken in this area in New Zealand is that of Kirk & Parker (1994b), who investigated the physiological workload of forest work. Whilst this work did not directly address the question of the influence of physiological and psycho-physiological stressors on safety, comfort, productivity and fatigue of breaker-outs, it did provide good indication of the type and severity of the physiological workloads associated with such work methods.

Two key features which play an important role in the creation of the forest worker's physiological and psycho-physiological stressors are the ambient thermal conditions, and the terrain of the work environment. The worker frequently has little control over these features, and subsequently, their impact on the safety, comfort, productivity and fatigue of the worker can be substantial. Implicitly tied to these two key features is the consideration of the person's working pace. It is this feature, when combined with one or both of the previous two, which often directly influences the workers safety, comfort, productivity and fatigue levels.

Ambient Thermal Conditions

Heat Stress

While fatal and/or even severe cases of heat strain are rarely reported in the New Zealand forest industry, the overall effect of undertaking hard physical work under hot conditions on logger safety, comfort and productivity is relatively unknown in New Zealand. As stated by Smith and Sirois (1982), there is a large body of literature concerning heat stress in general, but little directed specifically at forest harvesting tasks. The reason given is that most of the forest harvesting based ergonomics work has been undertaken in cold climate countries within Scandinavia. In these countries heat stress due to outside environmental conditions is not a frequent phenomenon.

The detrimental effect of heat stress on productivity in other countries has received some attention (FAO,1974). In some overseas cases, it has been suggested that it may in fact be more economical to shut down the harvesting operation temporarily than continue to operate at a reduced productivity (and thus higher unit cost) level while increasing worker long-term accumulated fatigue (Smith and Sirois,1982).

Heat stress disorders can vary in form and severity ranging from the less severe transient fatigue, chronic heat fatigue, skin eruptions, to the more severe heat syncope, and potentially fatal heat stroke. Heat stroke, in quite simple terms, can be regarded as the clinical manifestation of the failure of the thermoregulatory system of the body.

Increasing deep body temperature creates competition for blood between working muscles and the skin. Consequently, fatigue and exhaustion from heavy work will occur sooner, and recovery will take longer, in a hot environment than a cool one (Sanders and McCormick,1992). This influence will have a detrimental effect on work rate and overall productivity of the logger.

As previously mentioned, the breaker-out's work requires constant vigilance in order to prevent serious or fatal injuries from occurring. Ramsey and Kwon (1988) stated that vigilance and complex dual-tasks showed consistent performance decrements as temperature increased above 30 to 33^{o}C.

Cold Stress

Heat stress is only one side of the equation for forest harvesting operations within New Zealand. Most harvesting operations from approximately the Central North Island operations south, experience severe periods of cold at some stage throughout the year. The impact of cold on worker safety, comfort, productivity and physiological can be just as severe as heat stress impacts.

For people in cold air, cold stress generally produces severe discomfort before any effect on health occurs. There is therefore a strong behavioural reaction to cold and many methods used for its avoidance (Parsons, 1993). It is generally agreed that task proficiency decreases as a person's cold stress increases (Lockhart, 1966; Parsons, 1993; O'Leary, 1993). These changes affect both the physiological and psychological aspects of the person, with changes in arousal, reduced memory capacity and perception as well as severe mood and personality changes accompanying the onset of cold stress (Parsons, 1993).

Safety aspects of clearfell logging operations can also be severely affected by cold stress due to their fast and dynamic nature. As suggested by Enander (1984) and referred to by O'Leary (1993), impaired performance capabilities may not only reduce the amount and quality of work carried out, but also affect the ability of workers to counter unexpected hazardous situations.

Regardless of the specific rationale behind thermal stress related performance decrement, its potential impact on worker safety and productivity within the New

Zealand forest industry is extensive.

Identification of ambient thermal conditions factors will not ameliorate them, and worker training in ways to reduce the impact of such stressors must be undertaken if any real benefit is to be achieved. These findings are supported by Brown (1991) who, upon examining heat and cold in farm workers, stated few farmers have had any training in thermal stress evaluation. It would be safe to assume the same for the logging workforce within the New Zealand forest industry.

Terrain Conditions

Slope has shown to be an important factor in affecting worker productivity (Apud & Valdes, 1994) and workload (Wenbin et al, 1989, Trewin & Kirk, 1992, Kirk & Parker, 1994b). In steep terrain the use of equipment which is of the correct weight and design is of paramount importance (Tatsukawa, 1994). One major New Zealand forest company alone directly attributes 25% of its 1991 lost time accidents to steep and difficult terrain (O'Leary, 1992).

Working Pace

If a person works at a rate beyond his/her aerobic capacity, the heart rate, pulmonary ventilation, blood lactic acid and body temperature continue to rise throughout the period of exercise roughly proportional to the intensity of the work. The person becomes fatigued and there is a limit to the time during which he/she can work (Durnin & Passmore,1967).

Consequently, there has been considerable work undertaken in the past to determine the optimal working pace. During steady state work, sufficient oxygen is supplied to the working muscles by the aerobic metabolism and lactic acid does not exceed resting levels. If the work level intensifies and the aerobic metabolism can no longer supply all the required energy requirements, anaerobic metabolism commences and supplies the additional energy requirements. The negative aspect of this anaerobic contribution is lactic acid which is accumulated within the working muscles. This lactic acid is subsequently removed through oxidation during the following recovery period (Durnin & Passmore,1967).

As a consequence of earlier work undertaken by Astrand (1967); Michael (1960); Astrand and Rodahl (1986); Apud *et al.*(1989); Levine *et al.* (1982) and Evans *et al.* (1980) to name a few, it is accepted nowadays that a worker undertaking hard physical labour should not exceed on average 40% of their Vo_{2max} for an eight hour shift.

One way to mitigate the thermal and terrain impacts on workers would be through the introduction of rest pauses into the work routines. Such rest pauses could provide periods in which workers may be able to gain some respite from the physiological and psycho-physiological stressors effecting the worker.

The impact of rest breaks on worker productivity has been previously investigated (Alluisi and Morgan, 1982; Krueger, 1991; McCormick and Tiffin, 1974, Parker et al., 1993; Johnson & Tabor, 1987). As stated by Alluisi and Morgan, 1982 and cited by Parker *et al.*, 1993, short rest breaks in machine paced jobs do not reduce output even though less time is worked. Since a breaker-out's work pace is largely influenced by the mechanical ability of the extraction machine to extract a drag, and then return for then next one, such findings are applicable.

The reasons for maintaining productivity with shorter work time can be largely explained by the fact that, as stated by McCormick and Tiffin (1974), rest breaks serve to provide a relief from boredom, physiological stress, muscle fatigue and cardiac strain. The application of this rationale into the production forestry milieu has been suggested as a way to reduce physiological stress and muscle fatigue in breaker-outs (Johnson & Tabor, 1987), and boredom in logmakers (Parker *et al.*, 1993). The implementation of such an intervention into current work practices could play an important role in the reduction of fatigue and associated accidents within the forest industry workforce.

Objective

The objective of this study was to undertake an ergonomic investigation of hauler breaker-outs.

RESEARCH METHOD

Subjects

Two hauler crews were involved in the study with two breaker-outs from each crew being observed for one week each. All four subjects were experienced loggers, having an average of 10 ± 7 (S.D.) years experience (range 3 to 20 years) within the forest industry. The breaker-outs in crew A only performed that task. The breaker-outs observed in crew B worked a weekly job rotation system which meant that each member of the crew was assigned a different task at the beginning of the week. The purpose of this was to provide the crew members with increased variety in their work and to strengthen the skills base within the crew.

Both of crew A's breaker-outs, and one breaker-out from crew B were paid on a weekly wage basis which was not related to production. The other breaker-out of crew B was paid on a piece rate system which was linked to the tonnes extracted per day. Both crews worked from 7.00 am until 4.00 pm with two half hour rest breaks during the day at 10.30 am and 1.30 pm. Due to the steep terrain on which the breaker-outs worked, rest breaks were usually taken at their work site on the cutover.

Physiological Measures

Heart Rate

Heart rate was measured at one minute intervals for the entire working day using a hard-wired Polar Electro Sport Tester PE 3000 portable heart rate monitor (Figure 5). Non-work heart rate was taken from the subject while in a sitting position during the first rest break at the work site. As the subjects started work approximately 15 minutes before sunrise and due to the cold associated with that time of day, they did not want to be kept in a stationary position. Consequently, the next period of time when the subject was able to remain stationary for any length of time was during the first rest break. During this time the subject either sat down or lay flat on his back and slept. The subject's resting heart rate in this case was taken after a period of 15 minutes of inactivity.

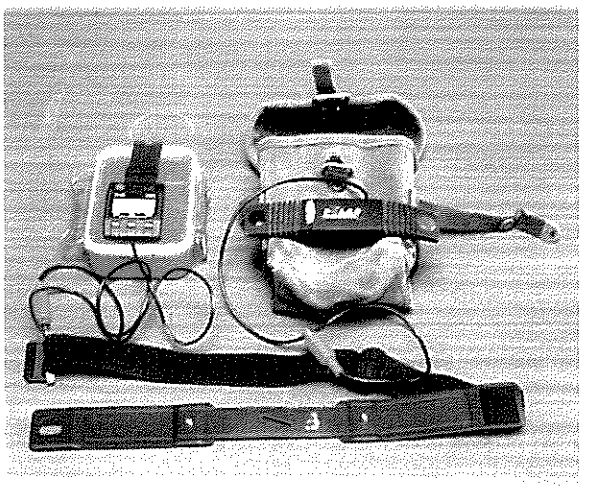


Figure 1 - Polar Electro Sport Tester PE 3000 portable heart rate monitor

Estimated VO^2max

Each breaker-out's maximum oxygen uptake (VO^2max) was estimated using the submaximal direct method while the breaker-out pedalled a "Cateye Ergociser" EC-1500 cycle ergometer (Åstrand and Rodahl, 1986). The Cateye Ergociser EC-1500 cycle ergometer used for the calibration technique is shown in Figure 6.

The subject exercised until he attained a steady state condition. The level of resistance was increased three times and the procedure repeated (Apud 1989). Heart rate (H/R) and energy expenditure (Watts) was recorded during the final steady state condition when the subjects H/R was within the 120 to 140 $bt.min^{-1}$ range.

Each subject's heart rate and energy expenditure figures were used to estimate his/her VO^2max using the nomogram in Astrand & Rodahl (1986). Regression equations were then formulated equating heart rate to oxygen consumption for each of the breaker-outs.

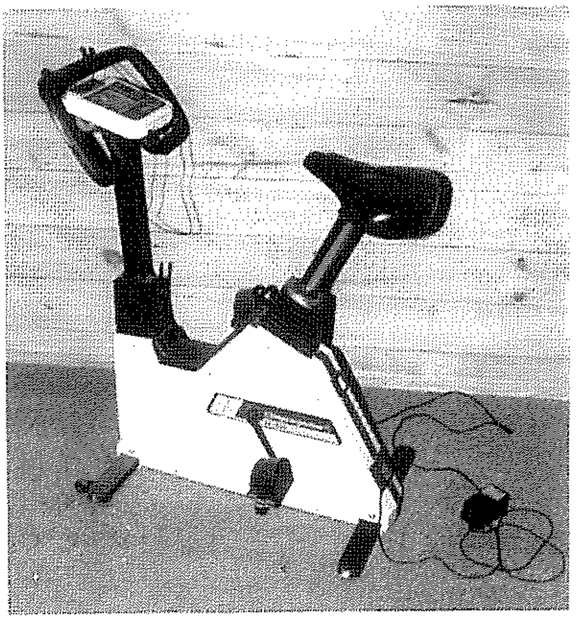


Figure 2 - The Cateye Ergociser EC-1500 cycle ergometer

Psycho-Physiological Measures

Perceived Rate of Exertion

Perceived rate of exertion was measured using the "Borg Category-Ratio (CR-10) Scale" (Appendix B) in an attempt to match the subjective psycho-physical rating of exertion with the objective physiological rating as measured by heart rate.

Each breaker-out rated his/her perceived degree of exertion immediately after each "hook up" activity. Working heart rates for the activity were then used to transform the physiological parameters into strain intensities using the equation $R = 0.0038 (HR - HR_0)^{1.7} + 0.5$ (Johansson and Borg (1993). This method enabled the researcher to rate how accurately the subject could rate his/her own perceived rate of exertion. (NB: HR = working heart rate and HR_0 = Resting heart rate + 10 $bt.min^{-1}$.)

Perceived Thermal Comfort and Sensation

Perceived thermal comfort and sensation was measured using an adapted questionnaire (Appendix C) based on the one used by O'Leary (1993). The questionnaire was applied at the start of the working day, at the start of each rest break and at the end of the working day .

Perceived Skin Wettedness and Thermal regulation

Perceived skin wettedness and thermal regulation was measured using an adapted questionnaire (Appendix D) based on the one used by O'Leary (1993). Here also, the questionnaire was applied at the start of the working day, at the start of each rest break and at the end of the working day .

Self Assessment of Fatigue

Self assessment of fatigue was measured at the start of the working day, at the start of each rest break and at the end of the working day using a questionnaire supplied by the Royal New Zealand Air Force (Legg,1992).

Production Measures

Work Activity

The subject's work activities were recorded using the continuous time study program "Siwork3" (Rolev,1990).The activities of the complete work cycle were separated into six standardised work elements and recorded on a "Husky Hunter" field computer.

Work Activity Elements:

In:	Walk from the gang vehicle (smoko) area into the extraction area.
Walk-in:	Walk from safety area to rigging to connect logs to strops.
Hook-up:	Connect logs to strops.
Walk-out:	Walk out to safe area after completing "hook-up".
Wait:	Wait at safety area for drag to be removed and rigging to return.
Out:	Walk out from extraction area to gang vehicle (smoko) area.

The heart rate and work activity data were merged using the spreadsheet package "Microsoft Excel Version 4.0". Subsequent analysis by the statistical package "Statistix" enabled mean heart rates for each element of the work cycle to be calculated.

Work Rate

Overall crew work rate was measured in terms of the number of drags extracted per hour and the total number of logs per drag. Individual breaker-out's work rate was measured by the number of logs he/she personally attached (hooked up) to the drag, as well as the number of logs he/she assisted with hooking up to the drag. From these measurements a percentage of primary and assisted hook ups per breaker-out per day was determined.

Terrain and Slope

Ground slope was measured in degrees using a Sunnto inclinometer to determine the predominant ground slope of the area in which the breaker-outs were working. Undergrowth hindrance was determined using the same subjective rating system as outlined in Kirk & Parker (1995) with 1 = low and 4 = extreme hindrance.

Ambient Climate Measures

Environmental Temperature

It has been well documented that ambient climatic conditions can have an impact on heart rate (Vitalis, 1981; Parsons, 1993; Sanders & McCormick, 1992; Rodahl, 1989). To ensure comparisons of workload could be made between days, dry bulb and wet bulb temperature were recorded at the extraction area as near as practically possible to the subject throughout the day. These measures were used to calculate the Oxford Index (WD) and relative humidity (RH) for each day of the study. The WD formula $WD = 0.85\, t_{nwb} + 0.15\, t_a$ (Parsons,1993) was used (NB: t_{nwb} = natural wet bulb, t_a = dry bulb temperatures.)

Manual recordings of wet and dry bulb temperatures were obtained using a whirling hygrometer. These recordings were then used to calculated the Oxford Index (WD) (Parsons,1993).

Safety

Hazardous Techniques

Hazardous techniques as defined by the Department of Labour "Safety Code for Bush Undertakings Part 2 - Cable Logging" were used to identify hazardous situations. The frequency and type of each hazard was also recorded. Hazard occurrence relative to time of day, environmental, system and experience factors was observed to see how hazard occurrences related to such factors.

RESULTS AND DISCUSSION

Study Location

The study was undertaken in Tasman Forestry Limited (Nelson District) Golden Downs Forest. Two separate hauler operations were observed during mid-June 1994.

Subjects

Two breaker-outs from each crew were observed for one week each, from Monday morning until Friday evening. Crew A's breaker-out team contained three men whereas crew B 's team contained only two men. The physical characteristics of each subject is shown in Table 1. Subjects 2 and 3 were characterised by mesomorphic body shapes, having heavy muscular builds. Subjects 1 and 4 possessed ectomorphic body shapes, being slim and slight of build. All subjects had moderate to high aerobic capacities (VO^2max) with a mean VO^2max recording of 59.4 $ml.kg^{-1}.min^{-1}$(range 42.4 to 70.8 ml.kg-1.min-1).

Table 1- Physical Characteristics of Subjects

Subject	1	2	3	4
Age (yrs)	43	26	27	19
Weight (kg)	70	84	80	65
Height (cm)	173	183	167	170
Body Mass Index	23.4	25.0	28.7	22.5
Resting Heart Rate ($bt. min^{-1}$)	60	54	53	65
Estimated VO^2max ($l. min^{-1}$)	3.0	4.4	4.8	4.6
Estimated VO^2max ($ml.kg^{-1}.min^{-1}$)	42.4	54.3	60.0	70.8
Pondural Index	0.42	0.42	0.39	0.42
Dubois Surface Area	$1.8m^2$	$2.0m^2$	$1.9m^2$	$1.7m^2$

Where: W = weight (kg), H = height (m)

Body Mass Index = $\frac{W}{H * H}$

20 = under weight
20 -25 = correct weight
25 - 30 = over weight

Pondural Index = $\frac{Height}{\sqrt[3]{Weight}}$

1 = Lean

0 = Obese

Dubio's Surface Area = $0.203 * W^{0.425} * H^{0.725}$

Both the body mass index (BMI) and pondural index would appear to place subject 3 in the overweight category. However, as previously stated, this subject was of a solid muscular build, and relatively short in stature. These features would therefore tend to bias these particular indices.

Production Measures

Table 2 - Crew A Production Data Summary

Mean Values	Day 1	Day 2	Day 3	Day 4
Slope (Degrees)	30.6	30.6	32	32
Pieces / Drag	2.5	3.0	3.0	3.1
Number of Strops	2	3	3	3
Hook on Time	2 min 5 sec	2 min 30 sec	2 min 54 sec	2 min 36 sec
Cycle Time	5 min 30 sec	6 min	6 min 54 sec	6 min 54 sec
N^{O} Drags/day	79	71	66	43
Total N^{O} Pieces / Day	197.5	213	198	133
Total Productive Time	7 hrs 12 min	7 hrs 6 min	7 hrs 36 min	4 hrs 54 min
Productive Time/Drag	5 min 28 sec	6 min	6 min 54 sec	6 min 48 sec

Note:

1. Cycle time is the time measured from when the empty butt rigging arrived at the breaker-outs, goes back to the landing with a drag, and then returns empty to the breaker-outs.

2. Total productive time does not include smoko times.

Crew A operated a highlead system throughout the course of the study. The normal working day provided approximately seven hours of productive time in which an average daily production of 72 ± 5 drags was achieved, the exception being Friday when the crew finished at 1 pm.

Figure 3 - Highlead system butt rigging containing 3 chain strops

Initially the butt rigging on day 1 contained only two chain strops. This was changed on day 2 however, with the addition of one extra chain strop (Figure 9). The influence of this can be seen in the increase in the average number of logs/drag, and increased hook up times in Table 2. The area being extracted was a convex slope varying in length from 340 to 420 metres (mean = 368 ± 45).

Ground slopes for the crew A study were extreme (Figure 10), ranging from 23 to 44^{o}, with a mean of 30.7 ± 3 ^{o}. Hindrance ratings ranged from 1 to 4, with the mean being 2.9 ± 0.6. This equates to high to extreme difficulty. This rating was a subjective measure determined by the researcher based on the slope and amount of debris and trees the breaker-outs had to climb over to attach the logs to the butt rigging. In crew A's case, both factors were in the upper limits for most of the study. Production cycle times were consistent, with hook up times ranging from two to three minutes and total cycle time averaging six to seven minutes.

No noticeable difference in drags/hour could be identified between the morning (am) and afternoon (pm) time periods (Table 3). Production was maintained at a consistent level throughout the working day with the exception for the time period which included the rest breaks.

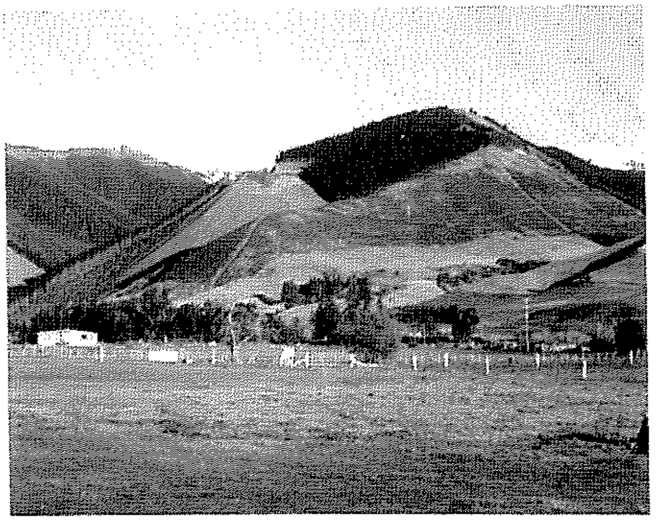


Figure 4 - Crew A Logging Site showing the 22 to 44^{o} slopes

Table 3 - Crew A Drags/Hour

Time	Day 1	Day 2	Day 3	Day 4
	07:18 - 16:02	**07:15 - 16:01**	**07:20 - 16:04**	**07:22 - 12:57**
7 -8	4	7	8	7
8 - 9	13	12	4	8
9 - 10	11	6	11	9
10 - 11*	4	1	4	4
11 - 12	9	13	9	7
12 - 13	10	13	9	8
13-14*	4	5	4	-
14 - 15	14	9	7	-
15 - 16	10	5	10	-
Total	79	71	66	43

* = Rest Breaks

Table 4 - Crew B Production Data Summary

Mean Values	Day 1	Day 2	Day 3	Day 4
Slope ^{o}	22.7	17.7	21.6	23.7
Pieces / Drag	3.0	3.0	4.1	4.6
Number of Strops	4	4	4	4
Hook on Time	2 min 17 sec	1 min 26 sec	1 min 59 sec	2 min 23 sec
Cycle Time	8 min 36 sec	4 min 35 sec	5 min 43 sec	7 min 17 sec
N^{O} Drags/day	55	46	84	36
Total N^{O} Pieces / Day	165	138	344	166
Total Productive Time	8 hrs 43 min	3 hrs 12 min	8 hrs 52 min	5 hrs 1 min
Productive Time/Drag	9 min 30 sec	6 min	6 min 18 sec	8 min 24 sec

Crew B operated a highlead system for day 1, then a scab skyline system for the remaining three days. This was due to the fact that on day 1 the crew were finishing off the last area of their old logging site in preparation for a move to an adjacent site the following day. The new site suited the use of the scab skyline system since it afforded some degree of deflection. Since scab skyline operations tend to provide faster cycle times than highlead operations, it was to the crew's advantage to use such a system whenever possible.

The "normal" working day provided approximately eight hours of productive time in which an average daily production of 75 ± 16 drags was achieved. As with crew A, the exception was Friday, when the crew finished at approximately 12 noon. The extraction site consisted of short dissected slopes varying in length from 293 to 361 metres (mean 327 ± 48). Slopes for the crew B study were less extreme than those experienced by crew A, ranging from 2 to 28 ^{o}, with a mean of 21.4 ± 5 ^{o}. Whilst the hindrance ratings for crew B also covered the full range of 1 to 4, the mean rating was 2.5 ± 0.7. The reason for the lower rating was primarily the fact that crew B were working on less steep slopes than crew A.

The impact of the scab skyline system (Figure 5) on cycle time can be seen in Table 4. However, these figures must be taken with some degree of caution. The cycle times for day 1 are representative of the long haul distances and general complications which are associated with the finishing up of a block. Days 2 and 3 however, have cycle times associated with the starting of a new block, since haul distances are relatively short as the wood to be extracted during the initial two or three days is close to the hauler.

Figure 5 - Scab Skyline Cable System

This is further borne out by the productive time/drag results for day 1 versus days 2 and 3. Day 4's cycle times were affected by the high production of day 3, and Friday's early finish time. The skid could not process wood as fast as the hauler and breaker-outs could extract it. As a consequence, the skid operated a "surge pile" system to accommodate the excess trees being extracted. The congestion that the operation of a "surge pile" arrangement produced, in turn detrimentally affected the operation of the skid. As a result, the crew foreman instructed the hauler to slow down in order to allow the skid crew to process the extra wood and enable the skid to function in an optimal manner. By doing so, no unprocessed trees would be left on the skid over the weekend period. Therefore the cycle times for day 3 were noticeably slower than the previous two days.

Table 5 - Crew B Drags/Hour

Time (Hours)	Day 1 07:30 - 16:22	Day 2 11:54 - 15:40	Day 3 07:21 - 16:07	Day 4 07:22 - 12:00
7 -8	4	¤	8	6
8 - 9	7	¤	12	7
9 - 10	10	¤	8	12
10 - 11*	4	¤	7	6
11 - 12	6	4	10	5
12 - 13	7	13	9	-
13- 14*	4	7	8	-
14 - 15	6	12	10	-
15 - 16	5	10	9	-
16 -17	2	-	3	-
Total	55	46	84	36

* = Rest Breaks ¤ = Moving Hauler to New Site

As with crew A, no noticeable difference in drags/hour could be identified between the morning (am) and afternoon (pm) time periods (Table 5). Production was maintained at a consistent level throughout the working day. The lower production at the end of day 1 can be attributed to the previously mentioned long haul distances and general complications which are associated with the finishing up of a block.

Likewise, the production figures for days 2 and 3 show the impact of short haul distances. This is most noticeably seen during the time periods which contain the rest breaks. On day 1 these periods followed the trend of crew A, producing on average four drags/hour. However, the move to shorter haul distances increased this average to seven drags/hour.

Table 6 - Percentage of Main and Assisted Drag Attachment

Subject	Main	Assist	Total
1	234 (73%)	86 (27%)	320
2	137 (86%)	23 (14%)	160
3	177 (91%)	16 (9%)	193
4	213 (88%)	29 (12%)	242

Table 6 shows that all four breaker-outs undertook their fair share of the work, averaging 84% main hook ups. This means that on average each breaker-out was involved in the act of hooking up logs to a drag for 84% of the time. The usual method for all the breaker-outs was to each select a strop and connect it to a log (Figure 12). If one breaker-out completed his task before his workmate, he would then take the remaining strop and attach this to a log. It was during this act of attaching the final strop, that the second breaker-out would then assist the first breaker-out.

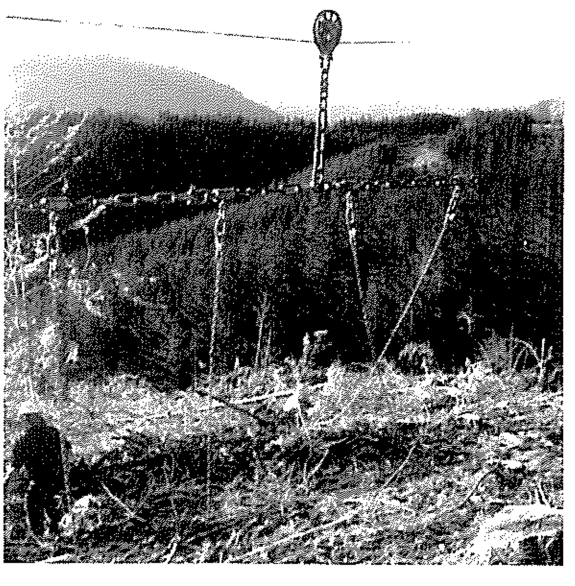


Figure 6 - Breaker-outs attaching chain strops to individual logs to form the drag

This measure was taken to see if any particular breaker-out undertook significantly more work than the other. This would be identifiable in that one subject would have a much higher "main" percentage that the other. This finding is not surprising as the breaker-outs must work as a team if they are to function effectively. As there are only two or three workers to a team, anyone not contributing equally would easily be identified and "persuaded" to increase their work rate.

Ambient Climate

The thermal index used was the Oxford Index (WD).

where: $\mathbf{WD = 0.85t_{wb} + 0.15t_{db}}$.

(twb = natural wet bulb temperature and tdb = natural dry bulb temperature)

Analysis of Variance (ANOVA) was used to determine if there were any significant differences between the daily ambient temperatures within each study, and then between the two studies.

Table 7 - Crew A mean daily Oxford Index temperature reading (^oC)

Day	Mean	S.D	n
1	4.9	1.6	9
2	5.0	2.4	9
3	7.0	1.9	9
4	4.8	1.1	6
Total	5.5	2.0	33

There was no significant difference in WD temperature between the days ($p > 0.05$).

Table 8 - Crew B mean daily Oxford Index temperature reading (^oC)

Day	Mean	S.D	n
1	8.0	0.7	7
2	6.6	0.3	4
3	4.9	1.8	9
4	5.7	2.0	6
Total	6.2	1.5	26

Day 1 was significantly hotter than the remaining days ($p = 0.003$). There was no significant difference between the remaining days ($p = 0.25$).

Table 9 - Oxford Index Comparison; Crew A versus Crew B (°C)

Crew	Mean	S.D	n
A	5.5	2.0	33
B	6.2	1.5	26
Total	5.8	2.0	59

There were no significant thermal differences in daily Oxford Index (WD) between the two crews studied ($p = 0.21$).

The ambient climatic conditions for both crews at the time of the studies consisted of cold days with occasional snow and rain. Consequently, little variation in WD temperatures was recorded.

Physiological Measures

Heart Rate

Table 10 - Subject 1: Heart rate indices by work task

Task	n	HR_W	S.D.	% Total Job	Ratio	%CVL	50% Level	HR_W 50% Level
Hook	595	115.4	13.7	34.0	1.92	41.65	128	0.90
Wait	621	89.3	11.5	35.4	1.49	22.03	128	0.70
Operational Delay	39	99.9	23.9	2.2	1.67	30.00	128	0.78
Line Shift	71	122.4	18.6	4.1	2.04	46.92	128	0.96
Uphill	130	122.0	20.7	7.4	2.03	46.62	128	0.95
Smoko	246	77.7	6.0	14.1	1.3	13.31	128	0.61
Down hill	49	110.0	9.7	2.8	1.83	37.59	128	0.86

Resting Heart Rate = 60. Age = 43.

Analysis of the heart rate indices for Subject 1, reveals that the most strenuous activities were line shifts, uphill travel and hooking on the drag. These findings back up observations made by the researcher at the time of the study, as these activities appeared to require the most physical effort from the breaker-outs. Line shifts involved moving the tail blocks to te next prepared backline stump and then pulling the slackened tailrope across the cutover for approximately five to 10 metres so that it could be fed back through the tailblock.

The heart rate graph shown in Figure 7 reveals the steady working pattern of Subject 1. He was the most experienced breaker-out of the team, and had a methodical and efficient work pattern. The two rest breaks can quite readily be seen from the heart rate recordings, as this is when the breaker-outs rested, drank and ate. These rest breaks were considered by both breaker-outs from crew A as being very important, and were therefore fully utilised.

Figure 7 - Subject 1 Complete Working Day Heart Rate Trace

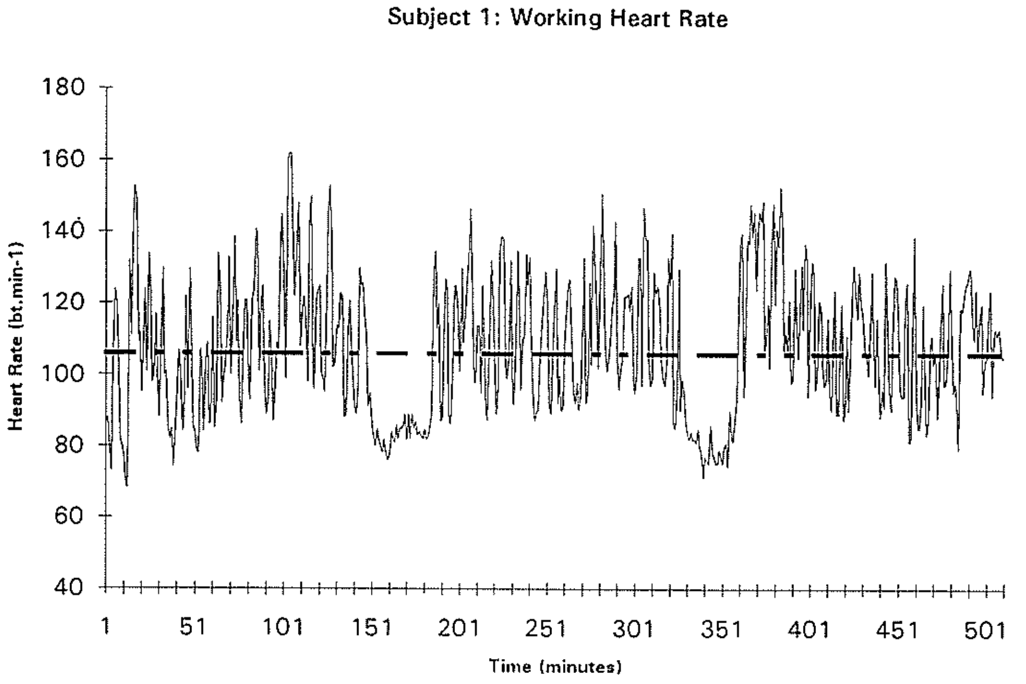


Table 11 - Subject 2: Heart rate indices by work task

Task	n	HR_W	S.D.	% Total Job	Ratio	%CVL	50% Level	HR_W 50% Level
Hook	453	117.6	14.3	29.7	2.18	45.76	122	0.96
Wait	534	89.8	13.7	35.0	1.66	25.76	122	0.74
Operational Delay	32	126.9	18.2	2.1	2.35	52.45	122	1.04
Line Shift	39	113.4	18.1	2.6	2.10	42.73	122	0.93
Uphill	160	137.8	21.8	10.5	2.55	60.29	122	1.13
Smoko	190	78.8	7.5	12.5	1.46	17.84	122	0.65
Downhill	94	105.7	16.2	6.1	1.96	37.19	122	0.87
Chainsaw	23	100.4	11.3	1.5	1.86	33.38	122	0.82

Resting Heart Rate = 54 Age = 26

Subject 2 was the less experienced and younger breaker-out of crew A's team. As a result he undertook a larger percentage of the tasks which required uphill travel and chainsaw work. Uphill travel for Subject 2 tended to be of a longer duration and of a more intense nature than that undertaken by Subject 1. The result of this can be seen in the heart rate indices, particularly the %CVL and HRw/50% Level, which are at the extreme levels of 60% and 1.13 respectively. As with Subject 1, line shifts and hooking on the drag, along with uphill travel, are the most strenuous work activities. In addition to these, operational delays consisting primarily of connecting logs which have worked free of the drag back to the drag, exerted high workload levels on Subject 2 - the reason being that such work often entailed short periods of rapid uphill travel combined with portions of both "hook" and "line shift" elements.

Figure 8 - Subject 2 Complete Working Day Heart Rate Trace

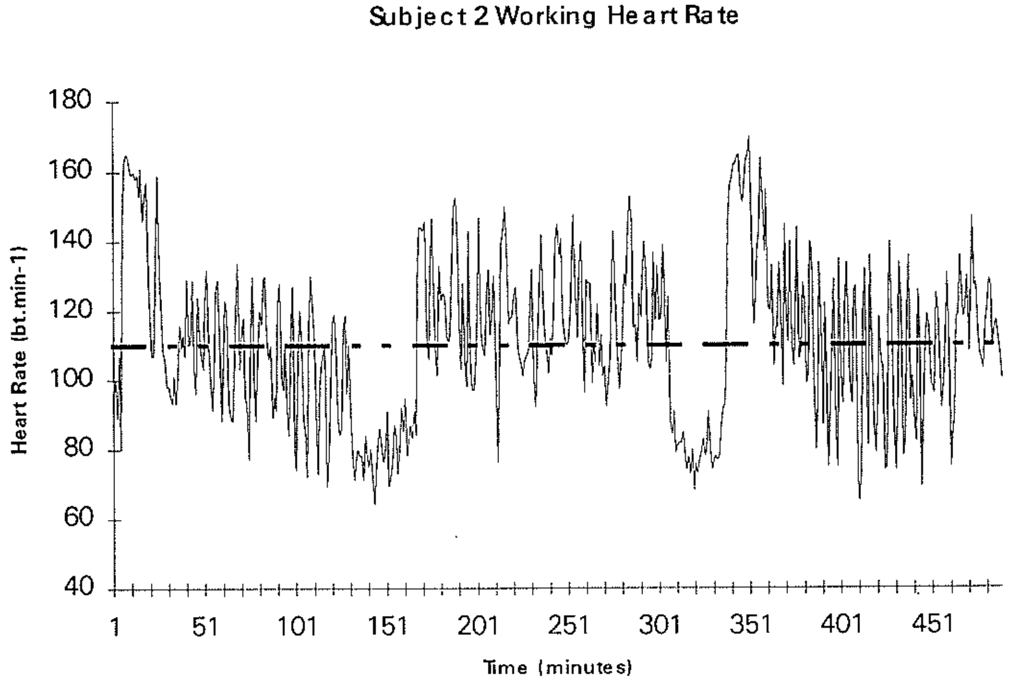


Figure 8 shows Subject 2's heart rate graph for one complete working day. The extreme workload associated with Subject 2's uphill travel is illustrated at approximately the 351 minute mark. At the conclusion of the second rest break Subject 2 proceeded to travel uphill, as indicated by the heart rate trace. The more erratic and intense working pattern of Subject 2 can be seen by the wide fluctuation in rising and falling heart rates during the day, particularly from the 381 minute mark onwards. The role of the rest breaks in providing a period in which the heart rate can recover is again illustrated with Subject 2.

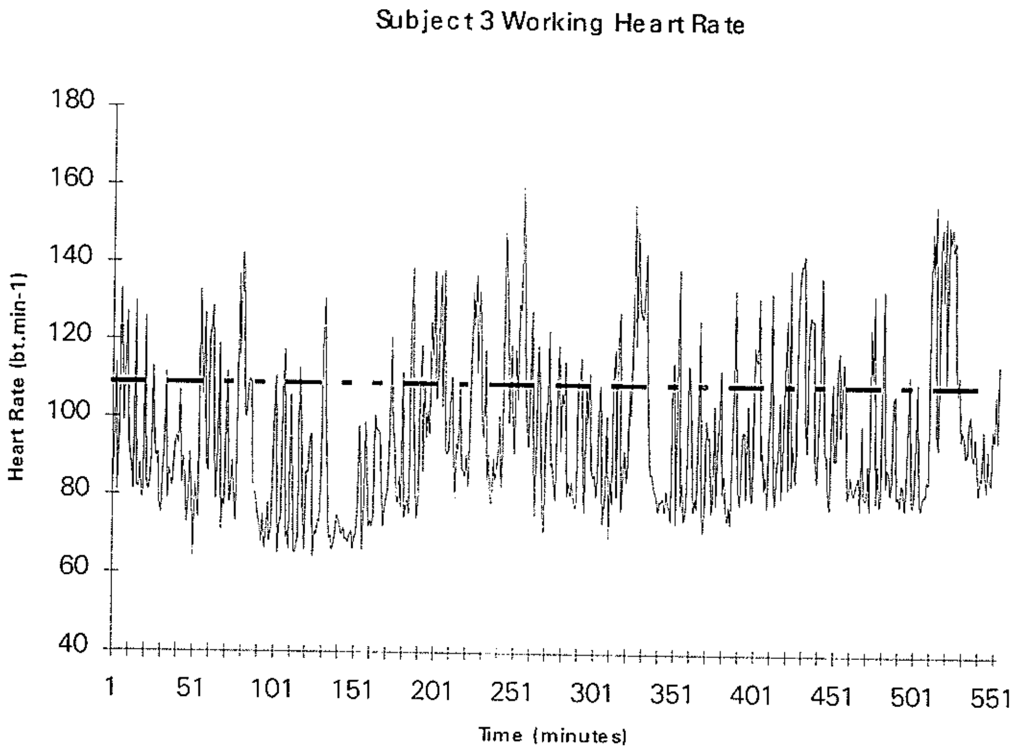
Table 12 - Subject 3: Heart rate indices by work task

Task	n	HR_W	S.D.	% Total Job	Ratio	%CVL	50% Level	HR_W 50% Level
Hook	507	113.7	14.5	29.2	2.15	43.36	121	0.94
Wait	798	84.0	10.9	46	1.58	22.14	121	0.69
Operational Delay	62	104.0	19.5	3.6	1.96	36.43	121	0.86
Line Shift	93	120.9	20.5	5.4	2.28	48.50	121	1.00
Uphill	55	109.7	21.0	3.2	2.07	40.50	121	0.91
Smoko	110	75.0	8.2	6.3	1.42	15.71	121	0.62
Pull Trees	23	91.4	18.1	1.3	1.72	27.43	121	0.76
Move Hauler	37	107.4	23.9	2.1	2.03	38.86	121	0.89
Down hill	51	87.8	13.4	2.9	1.66	24.86	121	0.73

Resting Heart Rate = 53, Age = 27

Line shifts, hooking on drags and uphill travel were also Subject 3's most strenuous work activities. Added to the normal work activities for crew B, were the activities associated with the moving of the hauler to a new site on the morning of the second day. This produced workloads of a similar level to uphill travel and operational delays, in the 38 to 41% CVL range.

Figure 9 - Subject 3 Complete Working Day Heart Rate Trace



The heart rate graph for Subject 3 shown in Figure 9 shows a quite different work pattern from those of Subjects 1 and 2 in that the rest breaks are difficult to identify. In crew B the breaker-outs appeared to place less value on the benefits of the rest breaks. These times were primarily seen as brief opportunities to eat as much food as possible within a short period of time (10 to 15 minutes).

The length of the rest break for the entire hauler crew was governed by the breaker-outs themselves, so no direct pressure was placed on them by the rest of the crew to have such short breaks. Since the majority of the crew's weekly income was dependent on the crew's combined daily production, it would be safe to assume this was the prime reason for such short rest breaks.

A further influencing factor contributing to the relatively short rest breaks was the climate at the time of the study, which was cold and wet. Since the breaker-outs' actual work site is located some distance away from the main body of the crew and the crew hut, they tend to take their breaks on the cutover adjacent to the extraction site. Such areas are devoid of all vegetation which may offer any form of protection from the elements. Therefore if it is cold and/or raining, there is little or no motivation to stop working since the body begins to cool rapidly. In such situations, food is eaten while standing, and the period of inactivity is kept to a minimum.

Table 13 - Subject 4 : Heart rate indices by work task

Task	n	HR_W	S.D.	% Total Job	Ratio	%CVL	50% Level	HR_W 50% Level
Hook	478	128.3	15.1	27.5	1.97	49.45	133	0.96
Wait	597	94.0	10.8	34.4	1.45	22.66	133	0.71
Operational Delay	24	89.4	7.3	1.4	1.38	19.06	133	0.67
Line Shift	185	124.5	23.1	10.6	1.92	46.48	133	0.94
Uphill	119	134.7	21.5	6.9	2.07	54.45	133	1.01
Smoko	119	85.3	6.7	6.9	1.31	15.86	133	0.64
Pull Trees	69	139.7	22.4	3.9	2.15	58.36	133	1.05
Move Hauler	24	116.9	12.6	1.4	1.80	40.55	133	0.88
Downhill	54	109.4	13.3	3.1	1.68	34.69	133	0.82
Chainsaw	14	139.3	12.0	0.8	2.14	58.05	133	1.05
Skid Work	54	126.7	13.0	3.1	1.95	48.20	133	0.95

Resting Heart Rate = 65, Age = 19

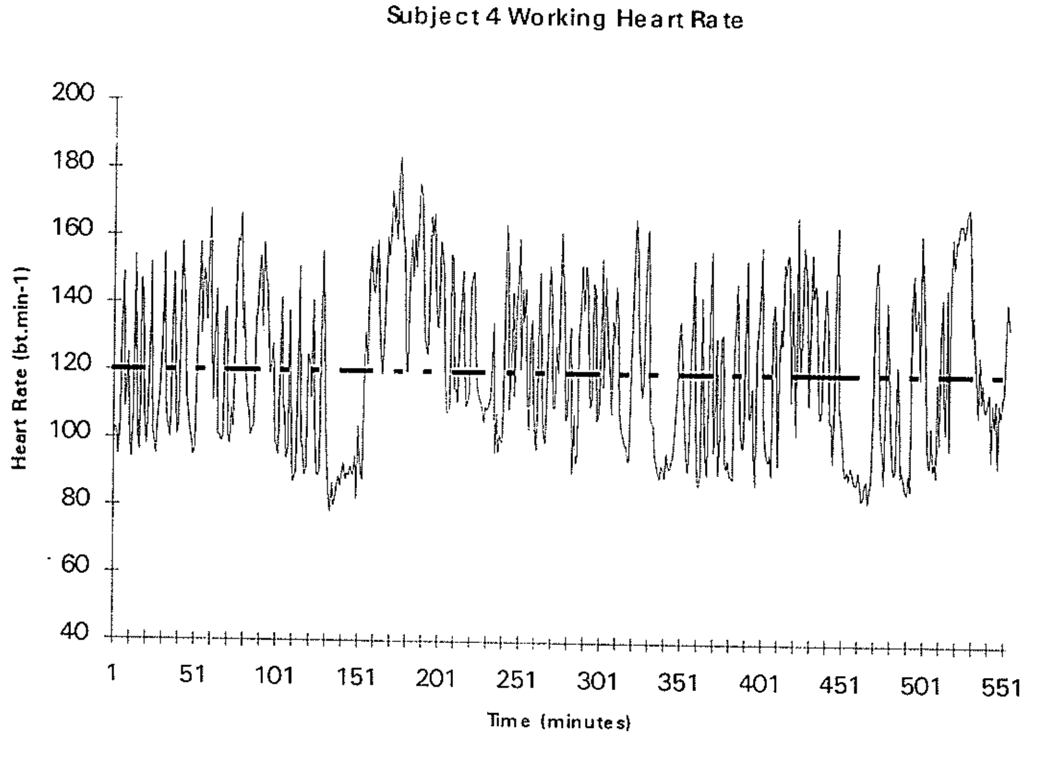
Subject 4 was the youngest and relatively least experienced of all the four breaker-outs studied. Here again, as with Subject 2 in crew A, he was the understudy of the senior breaker-out, Subject 3. Consequently he undertook additional work, usually at a more intense pace. As with the previous three breaker-outs, Subject 4 's most strenuous work elements were hooking on the drag, line shifts and uphill travel.

In addition to these standard work elements, Subject 4 undertook some additional activities which also produced significant workload levels. These activities involved the assisted felling and removal of trees located at the back boundary of the setting and using the hauler to pull the trees over in the required direction for easy extraction. The two main features of these operations which generated the high workload levels were the connecting of the strops to the trees, and the associated chainsaw work required for felling the trees.

Connecting the strops to the trees required the heavy chain strops to be lifted as high up the tree trunk as physically possible in order to obtain maximum leverage. The chain strops weighed approximately 15 kg each and proved difficult to lift above head height. The weight of the strops combined with the lifting action above head height, combined to produce workloads in the 58 % CVL range.

The high workloads associated with chainsaw work can be attributed to both the physical effort required to operate a chainsaw weighing approximately 10 kg over difficult terrain, and the nervous tension associated with the task at hand. Assisted felling of trees using a hauler, while being a certified assisted felling technique, is considered a very specialised and hazardous task. Consequently there was a certain degree of nervous tension observed within the breaker-out team during the undertaking of such operations.

Figure 10 - Subject 4 Complete Working Day Heart Rate Trace



As with Subject 3, no noticeable rest break can be easily identified in the heart rate graph shown in Figure 10.

Table 14 - Mean Working Heart Rate Indices/Subject

Subject	Age	n	HR_W (± S.D)	HR_r	% CVL	Ratio	50% Level	HR_W 50% Level
1	43	1505	105 (19.6)	60	38.4	1.75	118	0.89
2	26	1335	107 (22.8)	54	38.5	2.0	124	0.87
3	27	1626	98 (20.4)	53	31.9	1.84	123	0.79
4	19	1618	115 (23.4)	65	36.6	1.77	133	0.86
Mean (± S.D.)	28.8 (10.1)	1521 (135.7)	106 (6.9)	58 (5.6)	36.4 (3.1)	1.84 (0.11)	124.5 (6.2)	0.85 (0.04)

n = sample size, HRr = resting heart rate, HRw = working heart rate.

Table 14 shows the working heart rate averaged over the entire working day for each of the subjects. These figures have had a series of heart rate indices applied to them. The indices used were the relative heart rate at work index (%CVL), (Saha, 1978; Evans *et al*, 1980; Vitalis *et al*, 1994) ratio of working heart rate to resting heart rate, (Vitalis ,1981; Fordham *et al* 1978), 50% Level, (Lammert, 1972; Vitalis *et al*, 1994) and HR_W /50% Level (Vitalis *et al*, 1994).

Analysis of the mean working heart rates (106 bt.min^{-1} ± 6.9), indicates that hauler breaking out is a moderate workload activity (Rodahl 1986). The overall mean for the ratio of working heart rate to resting heart rate was 1.84 ± 0.1. This places breaking-out higher than that of nursing work 1.45 (Fordham *et al*, 1978), car assembly work 1.45 (Minard *et al*, 1971), steel workers 1.38 (Vitalis *et al*, 1994) and cane cutting 1.38 (Vitalis, 1981).

The relative heart rate at work index, % cardiovascular load (%CVL), indicates that all the subjects worked between the 30 to 40% aerobic capacity level recommended for prolonged continuous work (Åstrand and Rodahl, 1986; Apud *et al*, 1989). The mean being 36.3% ± 3.1. This can be attributed to the fact that whilst selected portions of the breaker-out's job place severe workload demands upon him (that is, uphill travel, line shifts and hooking up the drag), the occurence of frequent rest pauses mitigates the impact of such events on the overall workload level.

The 50% Level and HRw/50% Level indices further support these findings. Lammert (1972) suggested that the 50% Level can be successfully used as a simple and effective way of measuring strain. Lammert (1972) states that if heart rate at work/50% Level is equal to 1, then the work being undertaken can be classified as hard continuous work. Based on these findings the task of cable hauler breakingout methods fall short of this criterion having a mean value of 0.85 ± 0.04, and therefore cannot be classified as being hard continuous work.

The micro-pauses come about as the breaker-out must wait for the return of the empty butt rigging once the drag has been unhooked at the landing. This particular work element accounts for 37.7 ± 5.5 % of the breaker-out's total working time. The heart rate recordings shown in Figures 13 to 16 clearly show the rise and fall of the heart rates corresponding to the "Hook" and "Wait" phases of the production cycle. If it was not for such micro-pauses, the workload experienced by the breaker-outs would be significantly higher.

PSYCHO-PHYSIOLOGICAL MEASURES

Self Assessment of Fatigue

No significant ($p > 0.05$) changes in self assessed physical fatigue were determined when comparing the morning recordings with the afternoon recordings. To obtain a large enough sample size for statistical analysis, all four days' data per subject were combined. The self assessment of fatigue questionnaire and individual ratings from each subject are shown in Appendix A.

The lack of a significant difference between the two measures could be attributed to the conservative nature and central tendency of the responses which, as shown in Table 15, tended to average out within the mid value range (3 to 5). The fact that the ambient climate was on the cool side could have also affected the responses as the breaker-outs commented that the heat and humidity associated with summer operations tend to make them feel more fatigued than the cool conditions found in winter operations. There are numerous heat stress related research papers to support such statements, Hancock (1981); Rodahl and Guthe (1988) ; Nielsen *et.al.*, (1990); Tek and Olshaker (1992) to name a few.

Table 15 - Two Sample t-Test (P values); Fatigue: AM versus PM

	Questions					
Subject	1	2	3	4	5	6
1	0.5	0.16	0.20	0.22	0.32	0.34
2	0.06	0.06	0.06	0.80	0.18	1.0
3	0.1	0.12	0.37	0.44	0.41	0.24
4	0.3	0.44	-	0.35	0.79	0.44
Overall	0.5	0.16	0.20	0.22	0.32	0.34

Perceived Rate of Exertion (Modified CR-10 Borg Scale)

Unlike the tank truck drivers in the study by Johansson and Borg (1993), the subjects in this study were unable to accurately estimate their perceived rate of exertion using the "Borg Category-Ratio (CR-10) Scale" (Appendix B). Statistical linear model testing between actual measured heart rate and actual recorded strain intensities, gave a poor correlation co-efficient (mean 0.43 ± 0.2) and R^2's (mean 0.18 ± 0.18). The best results were gained from Subject 1 who had an R^2 of 0.41 and the worse was Subject 4 with an R^2 of 0.002.

Working heart rates for the activity of "Hook" were then used to transform the physiological parameters of each subject into strain intensities using the equation $R = 0.0038\ (HR - HR_0)^{1.7} + 0.5$ (Johansson and Borg, 1993). These were then compared to the actual strain intensities recorded by the subjects.

Table 16 - Correlation Co-efficient and R^2 ; Modified CR-10 Borg Scale

Subject	Test	Pearsons Correlation Co-efficient	Adjusted R^2
Total	Actual vs HR_w	0.20	0.04
Total	Actual vs HR_{wt}	0.26	0.06
Total	Actual vs HR_r	0.16	0.02
1	Actual vs HR_w	0.65	0.41
1	Actual vs HR_{wt}	0.65	0.40
1	Actual vs HR_r	0.67	0.43
2	Actual vs HR_w	0.53	0.24
2	Actual vs HR_{wt}	0.49	0.20
2	Actual vs HR_r	0.51	0.23
3	Actual vs HR_w	0.32	0.07
3	Actual vs HR_{wt}	0.29	0.05
3	Actual vs HR_r	0.31	0.06
4	Actual vs HR_w	0.20	0.002
4	Actual vs HR_{wt}	0.22	0.009
4	Actual vs HR_r	0.21	0.007

HR_w= Working Heart Rate. HR_{wt}= Waiting Heart Rate. HR_r= Resting Heart Rate

As with Johansson and Borg (1993), the HR_0 figure was obtained when the subject was not resting but also not working. In this case the most appropriate time to obtain such a recording was during the "wait" (HR_{wt}) phase of the productive cycle. During this time the subject was usually standing waiting for the return of the butt rigging. A second set of strain intensities was calculated using a second HR_0 figure. This second HR_0 figure was that of the subject's resting heart rate (HR_r).

Neither the (HR_{wt}) nor the (HR_r) calculated strain intensities produced better relationships between heart rate and strain intensity than those actually stated by the subjects themselves. Table 15 gives the correlation co-efficient and R^2 for each subject's test, as well as a combined (all subjects) test.

Thermal Comfort and Sensation

Table 17 - Two Sample t-Test (p values); Thermal Comfort & Sensation Ratings:AM versus PM

Subject	Comfort	Sensation
1	0.38	0.32
2	0.50	0.50
3	0.20	0.48
4	0.36	0.32

As with the fatigue measure, no significant change in self-assessed thermal comfort rating between the AM and PM periods of the day was identified. This could also be attributed to the cold ambient climate at the time of the study. The cold only appeared to affect the breaker-out's extremities, leaving the core of the body unaffected. The work of the breaker-out tended to keep the subject relatively warm. If the subject started to get too hot, he simply removed a layer of clothing. Consequently he was able to maintain a comfortable body temperature within set limits throughout the day. The thermal comfort and sensation questionnaires and individual ratings are shown in Appendix C.

Skin Wettedness and Thermal Regulation

Table 18 - Two Sample t-Test (p values); Skin Wettedness & Thermal Regulation Ratings: AM versus PM

Subject	Wettedness	Regulation
1	0.42	0.39
2	0.46	0.13
3	0.50	0.20
4	0.20	1.0

Again, no significant differences could be identified between morning and afternoon skin wettedness and thermal regulation ratings. Again the cool climatic factors prevailing at the time of the study could be attributed with causing this result. The same reasons given for the thermal sensation and comfort findings apply just as strongly here. As long as the subjects continued to work, their internal thermal environment was maintained at a comfortable level. The skin wettedness and thermal regulation questionnaires are shown in Appendix D. Individual subject ratings for skin wettedness and thermal regulation are shown in Appendix E.

Safety

Table 19 -Hazards/Time Period (All Days Combined)

Time	Subject 1	Subject 2	Subject 3	Subject 4
7 -8	2	0	0	0
8 - 9	11	9	1	1
9 - 10	26	16	1	0
10 - 11*	8	7	1	8
11 - 12	19	14	0	1
12 - 13	5	6	1	6
13- 14*¤	5	7	1	5
14 - 15¤	6	5	0	3
15 - 16¤	6	7	3	2
16 - 17¤			0	4
Total	88	71	8	30

* = Rest Breaks, ¤ = 3 Days Data Only (Friday early finish).

Table 20 - Hazard Frequency by Subject

Hazard	Subject 1	Subject 2	Subject 3	Subject 4
Avoidable Hazards				
1	8	10	1	0
2	17	22	2	5
3	21	21	0	1
4	0	1	3	5
5	1	0	0	0
6	7	1	0	0
7	0	3	1	15
8	8	0	0	1
9	0	0	1	3
Physical Hazards				
10	14	6	0	0
11	11	7	0	0
Total	88	71	8	30

Hazard Key:

1. Too close to moving drag.
2. Too close to moving cable.
3. In bight of rope.
4. Hit by empty strop.
5. Spiked by branch.
6. Handle moving rope.
7. Chainsaw related.
8. Cross moving rope.
9. Standing under sailer.
10. Falling boulders.
11. Rolling logs.

Table 21 - Hazard Frequency Analysis By Crew

Hazard	Crew 1	Crew 2	Sign. Diff ($p < 0.05$)
1	18	1	Yes
2	39	7	Yes
3	42	1	Yes
4	1	8	Yes
5	1	0	No
6	8	0	No
7	3	16	No
8	9	1	No
9	0	4	No
10	20	0	Yes
11	18	0	Yes
Total	159	38	Yes

Table 22- Hazard Analysis By Subject. (Total Hazards Combined) One Way ANOVA 95% Conf. Int

	Subject 1	Subject 2	Subject 3	Subject 4
Subject 1	---	(1 vs 2) Same $p = 0.544$	(1 vs 3) 1 Higher $p = 0.0037$	(1 vs 4) 1 Higher $p = 0.034$
Subject 2	(1 vs 2) Same $p = 0.544$	---	(2 vs 3) 2 Higher $p = 0.0005$	(2 vs 4) 2 Higher $p = 0.027$
Subject 3	(1 vs 3) 1 Higher $p = 0.0037$	(2 vs 3) 2 Higher $p = 0.0005$	---	(3 vs 4) 4 Higher $p = 0.033$
Subject 4	(1 vs 4) 1 Higher $p = 0.034$	(2 vs 4) 2 Higher $p = 0.027$	(3 vs 4) 4 Higher $p = 0.033$	---

A comparison of the hazards recorded during the study with the Logging Industry Accident Reprting Scheme (ARS) administered by the Logging Industry Research Organisation (LIRO), revealed that the study hazards were consistant with national accident trends (Parker, 1994). The national accident trends for breaking out hazards tended to be in the areas of "too close to ropes", "too close to the drag", "hit by ropes", "hit by dislodged material" and "hit by butt rigging". Two noticeable exceptions evident in the national database but absent from the study were, "strained back" and "injuries caused by slipping over".

A comparison of hazard frequency between the morning and afternoon time periods (Table 19), showed no significant difference between the two time periods for either crew A ($p = 0.0756$) or crew B ($p = 0.1262$). As shown in Table 20, Subjects 1 and 2 were exposed to both more avoidable hazards as well as natural hazards than either Subject 3 or 4. Each crew appeared to have site specific hazards as well as experience related hazards, depending on the breaker-out, environmental conditions and system being used.

Physical Hazards

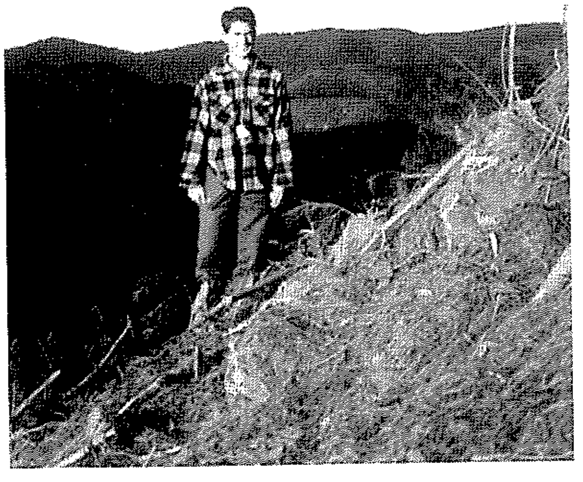


Figure 11 - Crew A work area upper slopes (44°)

The top high point of the area being worked by crew A contained a rock bluff located directly in the path of the extraction corridor. The result was that drags would collide with the bluff during the extraction phase dislodging large rock boulders which would the proceed downhill rapidly in the direction of the breaker-outs.

Added to this hazard was a second phenomenon which arose when logs within the drag would break free when it collided with the bluff. These logs would then slide downhill like spears towards the breaker-outs. This hazard increased substantially when it began to rain. The rain made the logs extremely slippery, making it easier for them to be dislodged from the drag. Once dislodged, the rain further increased the logs potential hazards by reducing the degree of traction offered by the ground cover. Consequently, such dislodged logs could travel considerably faster during periods of rain, than when conditions were dry.

Consequently, crew A had to contend with these additional physical hazards as well as the standard hazards associated with hauler breaking-out.

Cable System

Table 21, shows what impact the type of system being used has on breaker-out safety. For example, Subjects 1 and 2 had a combined total of 42 occurrences of being in the bight of the rope, hazard 3. Subjects 3 and 4 on the other hand only experienced one such situation - the key reason being that the highlead system being used by crew A provides "bight" situations as part of its layout between the back and tail blocks. The scab skyline system being operated by crew B on the other hand does not have this feature. This therefore severely reduces the "in bight of rope" type hazard.

Another example is hazard 6, "handle moving rope". Crew A incurred eight occurrences of this hazard whereas crew B incurred none at all. Here again the highlead system involves the cables being dragged along the ground as an integral part of the extraction process. As a result, the cable often becomes stuck behind debris such as old tree stumps and pieces of broken logs. In such situations some breaker-outs try to flick the cable over such obstacles as it is still moving. The scab skyline system has its cables lifted off the ground during both the extraction and gear return phases of the production cycle. The same principal applies to hazard 8 "cross moving rope".

Figure 12 - Suspended butt rigging of the scab skyline system

Hazard 4 "hit by empty strop" is an example of a hazard peculiar to skyline systems. As the gear is returned quickly to the breaker-outs via the suspended cables (Figure 12), the sudden stopping of the cable by the hauler driver causes the strops to swing violently around in the air. If a breaker-out is either too eager to get to the strop, or takes his eye off it at an inopportune moment, he can be struck by the swinging strop. As the chain strops in this study weighed approximately 15 kg each, they can inflict serious physical injuries. As highlead gear is returned on the ground, the possibility of being struck in such a manner is low, but not inconceivable.

Breaker-out Experience

It became quite evident during the study that an individual breaker-out's experience and attitude contributed considerably to their hazard exposure. Subject 1, for example, had considerable breaker-out experience with a range of haulers and systems, yet he displayed little respect for many of the hazards associated with the work. He took great care to ensure that his co-workers were in safe positions, but did not often apply the same care and concern to himself. Lark (1991) raises the concept of "optimistic bias" (this being that when discussing personal risks, people claim they are less likely to be affected than their peers). Weinstein (1989) has himself found this exact phenomena in numerous studies relating to different hazards. As a result, he strongly feels that the " It Can't Happen To Me" syndrome is not just a formula, it is a fact.

This should not be seen solely as an incrimination of this particular breaker-out since such a phenomenon has been widely identified in other research (Lark, 1991; Zimolong, 1985; Ostberg, 1979; Parker, 1991). There are numerous explanations why people take risks, including boredom, sensationalism, genetics, poor risk perception and familiarity with the risk. Zimolong (1985) states that a person's accepted risk level is established as a result of previous experiences and exposures to risk. In this particular case the constant exposure to risk has lead to familiarity with certain hazards and the development of poor risk perception.

This familiarity with certain hazards appeared to be influencing the less experienced Subject 2 to some degree. Slovic (1987) comments that a person's perception and acceptance of risk spring from the influence of family, friends and fellow workers or the influence of a social group. Table 21 shows that Subject 2 was exposing himself to the same types and frequencies of mainstream hazards as Subject 1, that is, hazards 1, 2 and 3. The difference between the two breaker-outs attitudes can be seen with hazards 6 and 8. It is these two hazards to which Subject 1 frequently exposed himself and could be considered to be "experience" influenced hazards.

The notable difference is that while Subject 2 is exposing himself to the mainstream hazards 1, 2 and 3, he is not doing so for the "experience" influenced hazards 6 and 8. This shows that Subject 2 still considers these last two hazards to be worthy of respect, something Subject 1 appears to have progressed on from.

Crew B's team had a significantly (p =

0.0002) lower hazard exposure frequencies than crew A's team. A large factor affecting this lower exposure frequency is, as previously mentioned, the operation of a different extraction system by crew B.

Comparisons between subjects are shown in Table 22. As can be seen, Subjects 1 and 2 showed no significant difference in hazards occurrence. However, when they were compared with Subjects 3 and 4, both had significantly higher hazard occurrences. Subject 3 was exposed to less hazard occurrences than 4. In this instance, Subject 4's higher hazard occurrence could be attributed to the fact that he undertook the task of felling the trees being pulled over by the hauler on day 1.

The findings from crew A highlight an area of possible concern in that when a new relatively inexperienced breaker-out joins the crew, he is usually assigned to work with the most experienced breaker-out. Such a move is the most logical thing to do as the experienced breaker-out should have the best understanding of the rules and workings of being a good efficient breaker-out. However, in obtaining this understanding it should be recognised that they may also have become too familiar with some of the associated hazards of the job and that such familiarity may be inadvertently passed on to fellow workers.

Such a situation may be addressed by the implementation of alternative techniques. For example, job rotation may reduce the chance of breaker-outs gaining a familiarity with the associated risks. The introduction of a random crew member into the breaker-out team for one day every fortnight may also enable that person to pick up poor work practices which would otherwise go unnoticed by the full time breaker-outs. The best analogy for such a situation is that of " you never notice your own children growing, but your friends always comment on how much they have grown". The same can be said for risk familiarity. An outside viewpoint of risks can identify hazards that may have become familiar within the day to day workings of the operation.

In summary, whilst it is difficult to determine and understand people's perceptions relating to risks, it is a task which must be attempted by everyone concerned (that is, worker, contractor and company) if continued advances in safety and health are to be achieved. Slovic (1991) makes a valid point in stressing that unless risk perceptions are understood by safety and health policy makers, a well-introduced policy may be totally ineffective.

Findings

Based on the relative heart rate at work (%CVL), ratio of working heart rate to resting heart rate, 50% Level, and HR_W /50% Level indices, the mean working heart rate (HR_W) of 106 bt.min^{-1} ± 6.9 (mean ± S.D) placed breaking out in the moderate workload category. The specific tasks of line shifts (120.3 ± 4.8 bt.min^{-1}), hooking up drags (118.8 ± 6.6 bt.min^{-1}) and uphill travel (126.1 ± 12.9 bt.min^{-1}), imposed the most severe workloads on the breaker-outs.

The HR_W for all four breaker-outs fell within the 30 to 40 % CVL level, (36.4 ± 3.1 %), recommended for eight hours continuous work (Rodahl,1989). The work routine of the breaker-outs entailed frequent short pauses (micro-pauses) throughout the normal working day. Such micro-pauses had a beneficial impact on the overall workload of the breaker-out in that they allowed the breaker-out's heart rate to recover from short periods of intense activity associated with specific work elements.

The cool thermal conditions present during both studies appears to have reduced the effectiveness of the self assessment of fatigue, thermal comfort and sensation, skin wettedness and thermal regulation ratings given by the breaker-outs. It is also felt that an increased sampling frequency could possibly improve the statistical power of such techniques by providing larger sample sizes.

There was a poor relationship between the breaker-outs' perceived rate of exertion, based on a strain intensity from the CR 10 Borg Scale, and the heart rate recorded for the corresponding time period. Applying the recorded heart rates to the modified CR-10 Borg Scale equation $R = 0.0038(HR - HRo)^{1.7} + 0.5$ developed by Johansson and Borg (1993), did not produce significantly stronger relationships.

Hazard type and frequency was significantly effected by physical hazards, logging system utilised and breaker-out experience.

REFERENCES

Alluisi, E.A. and Morgan, B.B. 1982. Temporal factors in human performance and productivity, Chapter 6. In E.A. Alluisi and E.A. Fleishman (Eds.), Human performance and productivity, Volume 3: Stress and Performance Effectiveness. Hillsdale, NJ: Lawrence Erlbaum.

Apud, E.,1989. Human Biological Methods for Ergonomics Research in Forestry. In Guidelines on Ergonomic Study in Forestry. (Eds) Apud, E., Bostrand, L., Mobbs, I.D. and Strehlke, B. International Labour Office, Geneva.

Apud, E. and Valdes, S. 1994. Physical Workload and Output for Planting on Grounds with Different Slopes. Proceedings of International IUFRO/NEFU/FAO Seminar on Forest Operations Under Mountainous Conditions with special attention to Ergonomics, Accessibility and Environmental Protection. Harbin, P.R. of China.

Åstrand, P.O. and Rodahl, K.,1986:"Textbook of Work Physiology". New York, McGraw Hill Book Company.

Beshir, M.Y., Ramsey, J.D. and Burford, C.L., 1982. Threshold values for the Botsball: A field study of occupational heat. *Ergonomics*, **25**, 247.

Botsford, J.A. 1971: "A Wet Globe Thermometer for Environmental Heat measurement". *American Industrial Hygiene Association Journal*, January. 1 - 10.

Brown, W.D. 1991. Heat and cold in farm workers. *Occupational Medicine: State of the art reviews*. **6**, 3, pp 371 - 389.

Enander, A. 1984. Performance and Sensory Aspects of Work in Cold Environments: A Review. *Ergonomics*, **27**, 4, 365 - 378.

Evans, W.J., Winsmann, F.R., Pandolf, K.B., and Goldman, R.F., 1980, Self-paced hard work comparing men and women. *Ergonomics*, **23**, 613 - 621.

Food and Agricultural Organisation of the United Nations. 1974. Logging and Log Transport in Man Made Forests in Developing Countries. FAO/SWE/TF 116, Rome.

Fordham, M., Appenteng, K. and Goldsmith, R. 1978. The cost of work in medical nursing. *Ergonomics*, **21**,331-342.

Gaskin, J.E., 1990: " An Ergonomic Evaluation of Two Motor-Manual

Delimbing Techniques". International Journal of Industrial Ergonomics Vol. 5, 211 - 218.

Gaskin, J.E.; Parker, R.J. 1992. Accidents in Forestry and Logging Operations in New Zealand, ILO/ECE/FAO Seminar, Corvallis, Oregon.

Johansson, S.E. and Borg, G. 1993. Perception of heavy work operations by tank truck drivers. Applied Ergonomics, 24 (6), 421 - 426.

Johnson, D. and Tabor, F.C. 1987. Body of Work. Northern Logger and Timber Processor, May, 8 - 18.

Kirk, P.M. 1992. Safety-Link Multi-Monitor Emergency Alarms Systems. LIRO Technical Note TN-8, August.

Kirk, P.M.;Parker, RJ.;Bradford, S.; Isler, R. 1992. Conspicuous Colours For Loggers Safety Clothing. LIRO Brief Report Vol 17 No 11.

Kirk, P.M.; Parker, R.J. 1993a. The impact of spiked boots on the safety, workload and productivity of breaking out. LIRO Brief Report Vol 18. No 3.

Kirk, P.M. & Parker, R.J.,1993b. Tough Tasks. NZ Forest Industries, June..

Kirk, P.M. 1993. Earmuff effectiveness against chainsaw noise over a 12 month period. Applied Ergonomics: Human Factors in Technology and Society. Volume 24 No 4. London. United Kingdom.

Kirk, P.M. & Parker, R.J. 1994a. The Effect of Spiked Boots on Logger Safety, Productivity and Workload. Applied Ergonomics: Human Factors in Technology and Society, Volume 24, No 2 . London. United Kingdom.

Kirk, P.M. and Parker, R.J. 1994b. Physical Demands of Steep Terrain Forestry Work in New Zealand. In proceedings of the International IUFRO/NEFU/FAO Seminar on Forest Operations Under Mountainous Conditions with special attention to Ergonomics, Accessibility and Environmental Protection. Harbin, P.R. of China.

Kirk,P.M. and Parker, R.J., 1995. An Ergonomic Evaluation of Chainsaw versus Manual First Lift Pruning of Douglas Fir in New Zealand.(In Press).

Kruger, G.P. 1991. Sustained Military Performance in Continuos Operations: Combatant Fatigue, Rest and Sleep Needs. United States Army Aeromedical Research Laboratory Report No 91 - 19.

Lammert, O. 1972, Maximal aerobic power and energy expenditure of Eskimo hunters in Greenland, Journal of Applied Physiology, **33**, 184-188.

Lark, J.1991. Risk Taking: Perspectives and Intervention. *Professional Safety*, November, 36 - 39.

Legg, S. 1992 Pers. Comm. RNZAF Base, Auckland.

Lockhart, J. 1966. Effects of body and hand cooling on complex manual performance. *Journal of Applied Psychology*, **50**, 57 - 59.

Mairiaux, P.H., Sagot, J.C. and Candas, V. 1983. Oral temperatures as an index of core temperature during heat transients. *European Journal of Applied Physiology*, **50**, 331 - 141.

McCormick, E.J. and Tiffin, J. 1974. Industrial Psychology. Englewood Cliffs, NJ: Prentice Hall.

Minard, D., Goldsmith, R., Farrier JR, B. H. 1971, Physiological evaluation of industrial heat stress, *American Industrial Hygiene Association Journal*, 32, 17-28.

O'Leary, C.M., 1992. Pers. Comm.

Olsen, P.F., 1989. The Cable Logging Resource. In proceedings of the Logging Industry Research Association Seminar "Cable Logging".

Östberg, O. 1979. Risk Perception and Work Behaviour in Forestry: Implications for Accident Prevention Policy. Accident Analysis & Prevention, Vol 12, 189 - 200.

Parker, R.J. 1991. Loggers' ranking of felling and trimming hazards, LIRA Report Vol.16 No.4.

Parker, R.J. 1992. Analysis of lost time accidents - 1991, LIRO Report Vol.17 No.8.

Parker, R.J; Cossens, P, and Strang, M, 1993. Human Factors in Log Making. LIRO Report Vol 18, No.17.

Parker, R.J. & Kirk P.M. 1993a. Physiological Workload of the New Zealand Forest Worker. New Zealand Institute of Forestry Conference Proceedings, Napier, May 1993.

Parker, R.J. 1993. Analysis of lost time accidents in logging - 1992. LIRO Report Vol.18 No.12.

Parker, R.J.; Kirk, P.M. 1993b. Felling and delimbing hazards. LIRO Report Vol. 18 No. 22.

Parker, R.J. 1994. Analysis of lost time accidents - 1993 Logging. LIRO Report Vol.19 No.9.

Ramsey, J., and Kwon, Y. 1988. Simplified decision rules for predicting performance loss in heat. *Proceedings on heat stress indices.* Luxemborg:Commission of the European Communities.

Rodahl,K. 1989, *The Physiology of Work.* Taylor and Francis, London.

Rodahl, K. and Guthe, T, 1988. Physical Limitations of Human Performance in Hot Environments, with Particular Reference to Work in Heat-Exposed Industry. In "Environmental Ergonomics; Sustaining Human Performance in Harsh Environments". Mekjavic, I.B., Banister, E.W. and Morrison, J.B. (Eds). Taylor & Francis, Philadelphia.

Rolev, A.M., 1990: "Siwork 3 Version 1.2: Work Study and Field Data Collection System". Danish Institute of Forest Technology, Amalievej 20, DK-Frederiksberg C, Denmark.

Saha, P.N. 1978, Aerobic capacity of steel workers in India, *Ergonomics*, **21**, 1021 - 1025.

Sanders, M.S. and McCormick, E.J., 1992. "Human Factors in Engineering and Design". 7th Ed. McGraw-Hill, New York.

Slovic, P. 1987. Perception of risk. *Science*, **236**, 280 -285.

Smith, L.A., and Sirois, D.L., 1982. Ergonomic research: Review and needs in southern forest harvesting. Forest Products Journal, **32**, (4), 44 - 49.

Spiers, J.J.K., 1985: "Loggers Language: A New Zealand Terminology". New Zealand Logging Industry Research Association, P.O. Box 147, Rotorua, New Zealand.

Tapp, L.; Gaskin, J.E.; Wallace, K., 1990. Loggers' assessments of risks in their work. LIRA Report Vol. 15 No. 1.

Tatsukawa, S. 1994. An Ergonomic Evaluation of the Cutting Work with a Light-Weight Chainsaw on Steep Terrain. In proceedings of the International IUFRO/NEFU/FAO Seminar on Forest Operations Under Mountainous Conditions with special attention to Ergonomics, Accessibility and Environmental Protection. Harbin, P.R. of China.

Tek, D and Olshaker, J.S., 1992: "Heat Illness". *Emergency Medicine Clinics of North America.* Vol 10, No.2, 299-310.

Trewin, A.R.D. & Kirk, P.M. 1992. Planting Bare-Rooted Seedlings of Radiata Pine on Difficult Terrain. Proceedings of the Logging Industry Research Organisation seminar on harvesting and re-establishment of difficult terrain, June 1992.

Vitalis, A., Gaskin, J.E. and Jeffrey, G., 1986: "The Physiological Cost of Work - An Ergonomics Approach". LIRA Report Vol.11 No.9.

Vitalis, *A.* 1981, An investigation of the relationship between pulse rate, environmental heat and work output of cane cutters in Fiji, unpublished Ph.D. Thesis, London University.

Vitalis, A.; Pournaras, N.D.; Jeffrey, G.B.; Tsagarakis, G; Monastiriotis, G. and Kavvadiast, S., 1994, Heart rate strain in Greek steelworkers. *Ergonomics*, **21**, (5), 845 - 850.

Weinstein, N.D. 1989. Optimistic Biases about Personal Risk. *Science* **246**, 1232 - 1233.

Wenbin, L., Tomomichi, F., and Shoji, I. 1989. Effects of Both Slope Angle and Weight of Brush Cutters on Forest Workers' Heart Rate and Walking Speed. Memoirs of the College of Agriculture, **34**, (1), 43 - 51 Ehime University.

Zimolong, B. 1985. Hazard Perception and Risk Estimation in Accident Causation. Trends in Ergonomics/Human Factors II , 463 - 470.

Appendix A

Self Assessment of Fatigue:

Self Assessment of Fatigue Questionnaire

How do you feel now?
(Please circle a number)

(Q1) Fresh	1	2	3	4	5	6	7	Weary
(Q2) Tense	1	2	3	4	5	6	7	Relaxed
(Q3) Strong	1	2	3	4	5	6	7	Weak
(Q4)Exhausted	1	2	3	4	5	6	7	Vigorous
(Q5)Wide Awake	1	2	3	4	5	6	7	Sleepy
(Q6) Bored	1	2	3	4	5	6	7	Interested

Fatigue: AM versus PM
Individual Ratings

Subject	AM Question						PM Question					
	1	2	3	4	5	6	1	2	3	4	5	6
1	5	3	3	3	1	3	6	2	6	6	2	3
1	7	4	7	2	2	5	6	5	6	5	4	5
1	6	5	6	3	3	6	7	6	6	5	3	5
1	6	5	5	3	3	3	5	3	4	4	1	3
2	3	2	4	3	1	3	3	5	4	3	1	5
2	2	5	2	3	1	6	5	4	4	5	2	3
2	2	5	3	5	1	5	4	5	4	5	5	4
2	3	6	3	5	4	4	2	6	2	6	2	4
3	2	6	2	6	2	5	6	5	5	4	5	2
3	6	2	6	3	2	2	5	5	4	4	5	4
3	6	6	6	2	6	2	5	6	5	4	6	3
4	4	6	4	5	6	3	5	6	6	4	5	3
4	5	5	4	4	3	4	6	5	6	3	5	4
4	5	6	5	4	5	2	-	-	-	-	-	-
Mean	4.4	4.5	4.3	3.6	2.9	3.9	5.0	4.8	4.8	4.5	3.5	3.7

Appendix B

Borg's Category-Ratio Scale (CR-10)

0	NOTHING AT ALL	
0.5	EXTREMELY WEAK	(JUST NOTICEABLE)
1	VERY WEAK	
2	WEAK	(LIGHT)
3	MODERATE	
4		
5	STRONG	(HEAVY)
6		
7	VERY STRONG	
8		
9		
10	EXTREMELY STRONG	(ALMOST MAXIMUM)
*	MAXIMAL	

Appendix C

Thermal Comfort Rating Questionnaire

	Overall
(1)Very Uncomfortable	____
(2)Uncomfortable	____
(3)Slightly Uncomfortable	____
(4)Not Uncomfortable	____

Thermal Sensation Rating Questionnaire

	Overall
(1)Very Hot	____
(2)Hot	____
(3)Warm	____
(4)Slightly Warm	____
(5)Neutral	____
(6)Slightly Cool	____
(7)Cool	____
(8)Cold	____
(9)Very Cold	____

Thermal Comfort & Comfort Ratings:AM versus PM
(Individual Ratings)

	Comfort		Sensation	
Subject	AM	PM	AM	PM
1	3	3	2	1
1	3	3	2	2
1	1	1	7	7
1	3	-	2	-
2	4	4	3	2
2	4	4	4	4
2	1	1	7	5
3	2	3	6	3
3	4	4	2	3
3	4	4	4	3
4	1	2	6	5
4	2	2	5	3
4	4	4	3	4
Mean	2.8	2.9	4.0	3.5

Appendix D

Skin Wettedness Questionnaire.

How does your skin feel ?.

More dry than normal	______
Normal dryness	______
Some parts of body moist	______
Main part of body moist	______
Some part of body wet	______
Main part of body wet	______
Sweat running off in some places	______
Sweat running off in many places	______

Thermal Regulation Questionnaire.

Are you ?...

Vigorously shivering	______
Moderately shivering	______
Slightly shivering	______
Neutral	______
Slightly sweating	______
Moderately sweating	______
Heavily sweating	______

Appendix E

Skin Wettedness and Thermal Regulation Ratings:AM versus PM (Individual Ratings)

	Wettedness		Regulation	
Subject	AM	PM	AM	PM
1	3	6	5	6
1	3	4	5	6
1	6	6	1	2
1	4	-	5	-
2	2	2	4	4
2	7	2	5	4
2	4	6	2	3
3	6	6	2	4
3	2	2	4	4
3	2	2	4	5
4	4	6	4	4
4	2	2	4	4
4	2	2	4	4
Mean	3.6	3.8	3.8	4.2