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**THE USE OF HEART RATE INDICES AND SUBJECTIVE
QUESTIONNAIRES IN THE DETERMINATION OF FATIGUE IN
MOTOR-MANUAL TREE FELLING AND DELIMBING
OPERATIONS IN NEW ZEALAND EXOTIC
PLANTATION FORESTS**

**A thesis submitted in partial fulfilment of the requirements for the
Degree of Master of Business Studies in Ergonomics at
Massey University.**

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1996

ABSTRACT

This study assessed the use of heart rate indices and subjective questionnaires in the determination of fatigue in motor- manual tree felling operations in New Zealand exotic plantation forests.

The research design consisted of a causal study utilising an amalgamation of both observational and ex post facto data collection techniques employing a cross sectional case study approach within a field study research environment.

Findings from the research indicate that motor-manual tree felling and delimbing are tasks not necessarily analogous with excessively high levels of fatigue, even though the physiological measures categorised motor-manual felling and delimbing as being moderate to heavy workload tasks. Chronic fatigue was avoided, and acute fatigue mitigated by the effective use of the fallers self-pacing mechanism, combined with both structured and spontaneous rest breaks analogous with the work method adopted by motor-manual fallers. Consequently, production was not negatively affected by the progression of the working day. Poor work postures commonly adopted by the fallers encourage the progressive development musculo-skeletal damage. Hazards encountered by the subjects followed national trends for felling and trimming. Significant decreases in thermal comfort and sensation ratings occurred, accompanied by an increase in the skin wettedness rating and higher thermal regulation ratings for the majority of the fallers. No discernible increase in mental fatigue could be identified during the study. The ambient thermal environment and work site terrain had minimal effect on the subjects performance levels or physiological and psycho-physiological loadings.

ACKNOWLEDGMENTS

The research reported in this thesis was funded by the New Zealand Logging Industry Research Organisation (LIRO). Accordingly, I wish to thank the LIRO Board of Directors and especially John Gaskin (Director), for providing both the opportunity and support to carry out this research. I would like to thank my bodatious colleagues Mark Sullman and Richard Parker for their most excellent assistance with this study, and Janelle Byers (Bob) for her impressive grammatical abilities.

I would also like to thank my supervisor Professor Antonious Vitalis for his excellent comprehension of the problems and practicalities associated with undertaking applied research within the forestry sector.

A special thanks goes to all of the contractors and workers who agreed to take part in this study. Their agreeable and willing attitudes played a large part in the success of this study.

Of all those that I must thank, by far the most important and special of all to me is that of my wife Pam. I thank her for the endless and undying support over the last two years. Without which, none of the work could have been started, let alone completed.

All that I can say now is, that enough is enough, and here endith my progression up the ladder of Academia, its now time for deer stalking!!.

Table of Contents

	Page
Abstract	ii
Acknowledgments	iii
Table of Contents	iv
List of Figures	xi
List of Tables	xiii
 Chapter One: Introduction to Commercial Forestry	 1
1.0 Introduction	1
1.1 New Zealand Commercial Forestry	1
1.2 The New Zealand Logging Workforce	2
1.3 Future Developments	3
1.4 Manual Forestry Work	3
1.5 Summary	5
 Chapter Two: Literature Review	 6
2.0 Introduction	6
2.1 Fatigue	6
2.2 Thermal Load	10
2.2.1 Effect of Heat on Performance	11
2.3 Physical Work Environment	13
2.4 Work Rate	14
2.5 Psychological State	15
2.5.1 Perception of Physiological Demands	15
2.5.2 Discomfort Survey's	17

2.6 Physical Capacity	18
2.6.1 Oxygen Consumption	18
2.6.2 Heart Rate	19
2.6.3 Energy Expenditure	21
2.7 Summary	22
 Chapter Three: Description of the Experiment	 23
3.0 Introduction	23
3.1 Daily Time Table in the Field	23
3.2 Operational Planning	24
3.3 Felling Equipment	26
3.4 Timber Extraction	27
3.5 The Mechanics of Tree Felling	28
3.6 Delimbing Methods	29
3.7 Summary	31
 Chapter Four: Methodology	 32
4.0 Introduction	32
4.1 Research Design	32
4.1.1 Limitations	32
4.2 Subjects	32
4.2.1 Weight	33
4.2.2 Stature	33
4.2.3 Body Mass	34
4.3 Sample Size	34
4.3.1 Felling Cycles	34
4.3.2 Heart Rate Recordings	35
4.4 Subject Recruitment	35

4.5	Ethical Approval	36
4.6	Physiological Responses	36
4.6.1	Heart Rate	36
4.6.1.1	Working Heart Rate (HR_w)	36
4.6.1.2	Resting Heart Rate (HR_r)	38
4.6.1.3	Percent Heart Rate Range (%HRR)	39
4.6.1.4	Work Pulse	40
4.6.1.5	50% Level of Heart Rate Reserve	40
4.6.1.6	Ratio HR_w/HR_r	40
4.6.2	Calibration of Heart Rate Monitors	40
4.6.3	Aerobic Capacity	41
4.6.3.1	Estimated Oxygen Uptake	41
4.6.3.2	Estimated Aerobic Capacity	41
4.6.3.3	Relative Estimated Aerobic Capacity	41
4.6.3.4	Estimated Energy Expenditure	42
4.7	Production	43
4.7.1	Cycle Times	43
4.7.2	Percentage Time per Task	43
4.7.3	Time Study Elements	43
4.7.4	Volume per Day	43
4.8	Terrain	44
4.8.1	Ground Slope	44
4.8.2	Undergrowth Hindrance	44
4.9	Hazards	44
4.9.1	Hazardous Felling and Delimbing Techniques	44
4.9.2	Hazard Ratios	45
4.10	Psycho-Physiological Measures	45
4.10.1	Rate of Perceived Exertion (RPE)	45
4.10.2	Self Assessment of Fatigue	46
4.10.3	Body Part Discomfort (BPD)	46
4.10.4	Perceived Thermal Comfort and Sensation	47
4.10.5	Skin Wettedness	47
4.10.6	Thermal Regulation	47
4.10.7	Digit Symbol Substitution (DSS)	48
4.11	Ambient Thermal Environment	49
4.11.1	Calibration of CR-21 Weather Station	49
4.11.2	Summary	49

Chapter Five: Results	50
5.0 Introduction	50
5.1 Subjects	50
5.1.1 Physical Characteristics	50
5.2 Physiological Responses	51
5.2.1 Heart Rate Indices	51
5.2.2 Aerobic Capacity and Oxygen Consumption	52
5.3 Production	54
5.3.1 Cycle Times	54
5.3.2 Percent Time per Task	54
5.4 Terrain	56
5.5 Hazards	56
5.6 Psycho-Physiological Measures	57
5.6.1 Rated Perceived Exertion	57
5.6.2 Subjective Fatigue Ratings	58
5.6.3 Body Part Discomfort	59
5.6.4 Thermal Comfort	61
5.6.5 Thermal Sensation	62
5.6.6 Skin Wettedness	63
5.6.7 Thermal Regulation	64
5.6.8 Digit Symbol Substitution	65
5.7 Ambient Thermal Environment	69
5.8 Summary	70
Chapter Six: Discussion	71
6.0 Introduction	71
6.1 Subjects	71
6.1.1 Height and Body Mass	71
6.1.2 Summary	72
6.2 Physiological Measures	72
6.2.1 Heart Rate Indices	72
6.2.1.1 Working Heart Rate	72
6.2.1.2 Relative Heart Rate at Work	74
6.2.1.3 Work Pulse	76
6.2.1.4 Working Heart Rate/50% Level	77
6.2.1.5 Ratio of Working Heart Rate to Resting Heart Rate	78

6.2.1.6	Estimated Oxygen Consumption	78
6.2.1.7	Estimated Energy Expenditure	79
6.2.1.8	Summary	82
6.3	Production	83
6.3.1	Summary	85
6.4	Terrain	85
6.4.1	Summary	86
6.5	Hazards	86
6.5.1	Summary	89
6.6	Psycho-Physiological Measures	90
6.6.1	Rate of Perceived Exertion	90
6.6.1.1	Summary	91
6.6.2	Subjective Fatigue	91
6.6.2.1	Summary	92
6.6.3	Body Part Discomfort	92
6.6.3.1	Summary	95
6.6.4	Thermal Comfort, Sensation, Skin Wettedness and Regulation	95
6.6.4.1	Summary	96
6.7	Digit Symbol Substitution	97
6.7.1		99
6.8	Ambient Thermal Environment	99
6.8.1	Summary	100
6.9	Summary	100
Chapter Seven: Conclusions		101
7.0	Introduction	101
7.1	Physiological Indices	101
7.2	Production	101
7.3	Terrain	102
7.4	Hazard Analysis	102
7.5	Rate of Perceived Exertion	102

7.6 Subjective Fatigue	102
7.7 Body Part Discomfort	103
7.8 Thermal Comfort, Sensation, Skin Wettedness and Thermal Regulation	103
7.9 Digit Symbol Substitution	103
7.10 Ambient Thermal Environment	104
7.11 Summary	104
Chapter Eight: Recommendations	105
8.0 Introduction	105
8.1 Heart Rate Indices	105
8.2 Rest Breaks	105
8.3 Personal Protective Equipment	106
8.4 Mechanisation	106
8.5 Summary	106
Chapter Nine: Future Research	107
9.0 Introduction	107
9.1 Musculo-skeletal Disorders	107
9.2 Fluids and Nutrition	107
9.3 Mental Workload	108
9.4 Summary	108
References	109
Appendices	
Appendix A: Study Consent Form	127
Appendix B: Information Sheet	128
Appendix C: Borg RPE Scale	129
Appendix D: Self Assessment of Fatigue Questionnaire	130
Appendix E: Body Part Discomfort Survey	131

Appendix F: Thermal Comfort, Sensation, Skin Wettedness and Thermal Regulation Questionnaires	132
Appendix G: Digit Symbol Substitution Test	133
Appendix H: Glossary of Terms	134

LIST OF FIGURES

List of Figures

	Page
Figure 1: Combined Effect of Everyday Causes of Fatigue.	9
Figure 2: Factors Affecting Physical Performance.	9
Figure 3: Model for Considering the Effects of the Thermal Environment on Human Activity, Performance and Productivity.	10
Figure 4: Plan View of Felling Face Layout and Operation.	24
Figure 5: Faller Working the Felling Face.	25
Figure 6: Faller Wearing His Helmet, Ear Protectors, Protective Legwear and Felling Belt.	26
Figure 7: Grapple Skidder Extracting Felled and Delimbed Stems From The Cutover.	27
Figure 8: Freshly Felled and Extracted Stems on the Skid Awaiting Processing.	28
Figure 9: Cross Sectional View of Tree Felling Cuts.	29
Figure 10: Plan View of Tree Felling Cuts.	29
Figure 11: Poor Posture Adopted During Delimbing of the Stem.	30
Figure 12: Faller Delimbing Methods.	31
Figure 13: Pe3000 Portable Heart Rate Monitor, Protective Case and Carry Pouch.	38
Figure 14: Faller Wearing Pe3000 On His Belt In The Carry Pouch.	39
Figure 15: Cateye Ergociser EC-1500 Cycle Ergometer.	42
Figure 16: Faller Undertaking Psycho-Physiological Tests.	46
Figure 17: Predicted Oxygen Uptake (l.min^{-1}).	52
Figure 18: Average Daily and Hourly Production in Cubic Metres (m^3).	55
Figure 19: Mean Hazard Type and Percentage Occurrence.	56
Figure 20: Subject 1 Mean Weekly Discomfort and Severity Rating.	59
Figure 21: Subject 2 Mean Weekly Discomfort and Severity Rating.	59

Figure 22: Subject 3 Mean Weekly Discomfort and Severity Rating.	59
Figure 23: Subject 4 Mean Weekly Discomfort and Severity Rating.	60
Figure 24: Subject 5 Mean Weekly Discomfort and Severity Rating.	60
Figure 25: Subject 6 Mean Weekly Discomfort and Severity Rating.	60
Figure 26: Mean Weekly Thermal Comfort Ratings.	61
Figure 27: Mean Weekly Thermal Sensation Ratings.	62
Figure 28: Mean Weekly Skin Wettedness Ratings.	63
Figure 28: Mean Weekly Thermal Regulation Ratings	64.
Figure 30: Subject 1 Mean Daily DSS Score.	65
Figure 31: Subject 2 Mean Daily DSS Score.	65
Figure 32: Subject 3 Mean Daily DSS Score.	66
Figure 33: Subject 4 Mean Daily DSS Score.	67
Figure 34: Subject 5 Mean Daily DSS Score.	67
Figure 35: Subject 6 Mean Daily DSS Score.	68
Figure 36: Mean Hourly % Relative Humidity and Wet Bulb Globe Temperature (wbgt).	69
Figure 37: Summary of Overall Energy Consumption Compared With Working Consumption.	81

LIST OF TABLES

	Page
Table 1: Subjects Physical Characteristics.	50
Table 2: Mean Daily Heart Rates at Work and Rest.	51
Table 3: Mean Working Heart Rate; Morning (AM) versus Afternoon (PM) (mean \pm S.D.).	51
Table 4: Estimated Aerobic Capacity and Estimated Mean Oxygen Consumption During Work.	52
Table 5: Predicted Workload/Oxygen Uptake Relationships.	52
Table 6: Mean Estimated Rates of Energy Expenditure.	53
Table 7: Mean Total Cycle Time Per Stem, Morning (AM) versus Afternoon (PM).	54
Table 8: Percentage of Day Undertaking Each Task.	54
Table 9: Mean Hourly Production (m^3/hr); Morning (AM) versus Afternoon (PM).	55
Table 10: Mean Weekly Hazard Ratio, Frequency and Location.	56
Table 11: Hazard Ratio (Hazards/100 stems); Morning (AM) versus Afternoon (PM).	57
Table 12: Mean Daily Rated Perceived Exertion (RPE).	57
Table 13: Weekly Average Fatigue Trends; Morning (AM) versus Afternoon (PM).	58
Table 14: Mean Weekly Thermal Comfort Ratings; Morning (AM) versus Afternoon (PM).	61
Table 15: Mean Weekly Thermal Sensation Ratings; Morning (AM) versus Afternoon (PM).	62
Table 16: Mean Weekly Skin Wettedness Ratings; Morning (AM) versus Afternoon (PM).	63
Table 17: Mean Weekly Thermal Regulation Ratings; Morning (AM) versus Afternoon (PM).	64
Table 18: Subject 1 Mean Daily DSS Score; Morning (AM) versus Afternoon (PM).	65

Table 19: Subject 2 Mean Daily DSS Score; Morning (AM) versus Afternoon (PM).	66
Table 20: Subject 3 Mean Daily DSS Score; Morning (AM) versus Afternoon (PM).	66
Table 21: Subject 4 Mean Daily DSS Score; Morning (AM) versus Afternoon (PM).	67
Table 22: Subject 5 Mean Daily DSS Score; Morning (AM) versus Afternoon (PM).	68
Table 23: Subject 6 Mean Daily DSS Score; Morning (AM) versus Afternoon (PM).	68
Table 24: Mean Hourly WBGT and Relative Humidity Morning (AM) versus Afternoon (PM).	70
Table 25: Rating of Work Energy Expenditures.	80
Table 26: Physiological Classification of Working Activities.	82

CHAPTER 1: INTRODUCTION TO COMMERCIAL FORESTRY

1.0 Introduction

This chapter begins with a brief history of plantation forestry in New Zealand, the resource and the labour force. It then outlines the current and future labour requirements for both current and projected harvesting trends within the industry. The final section outlines past and present ergonomic research relating to manual forestry work in New Zealand.

1.1 New Zealand Commercial Forestry

Forestry is one of the oldest occupations known to New Zealanders. Even before the whaling and sealing colonies were established during the late 1700's and early 1800's, Europeans had been involved in the extraction of *Agathis australis* (Kauri) poles for use as ship spars. Before European settlement, the indigenous forest was an important aspect of the culture of the Polynesian (Maori) population which inhabited New Zealand from ca 1000 AD. They harvested the forest for fuel wood, shelter and, using fire, cleared areas for the purpose of raising food crops.

Commercial, or plantation, forestry commenced at the beginning of the 20th century. It was recognised that the indigenous forests could not provide the lumber requirements of the rapidly growing colony. Plantation forestry boomed during the great depression of the 1930's, when large scale planting of predominantly *Pinus radiata* was undertaken to provide gainful employment for the large number of people who were jobless during this period. This was the first evidence of the importance of plantation forestry to the nation and the employment opportunities it could provide.

In 1995, New Zealand contained 1,308,000 hectares (ha) of exotic forestry of which 89.9% was planted in *Pinus radiata*, 5.1% Douglas Fir (*Pseudotsuga menziesii*) the remaining 5% consisted of a mixture of exotic softwoods (3%) and exotic hardwoods (2%) (Forestry Facts and Figures 1995). In April 1992 (latest available figures), only 16% of the total *Pinus radiata* resource fell into the clearfell age class of 25 + years old.

More significantly, a further 43% of the total *Pinus radiata* resource was between 5 to 10 years away from clearfell age class (Forestry Facts and Figures, 1995).

Between 1920 and 1990, the annual rate of new planting's peaked at approximately 57,000 ha per year up until the early 1980's when this rate decreased dramatically in line with both the standardisation of all land based production incentives (Le Heron 1985) and the economic recession instigated by the share market crash of 1987. Since the early 1990's an increased interest in forestry investments in the form of joint venture retirement and superannuation schemes, combined with the more traditional farm based woodlot establishments, has seen the rate of new planting's increase dramatically from around 17,000 ha per year in 1990 to an estimated 85,000 ha per year in 1995 (Forestry Facts and Figures 1995). The beneficial consequences of such a trend, in terms of the continuance of a viable wood fibre source for the forestry sector, are substantial.

1.2 The New Zealand Logging Workforce

In February 1994, there were 8548 people employed in the logging and silviculture workforces in New Zealand (Forestry Facts and Figures 1995). Current figures are unavailable on the exact distribution between these two groups. However, an indication can be gained from the previous year's figures which, for a total workforce of 7394 workers, placed 4552 in silviculture and 2842 in logging (Forestry Facts and Figures, 1994). The average \pm (sd) age of the logging workforce in June 1995 was 31.4 ± 8.9 years. The average logging experience for the workforce was 8.4 years. Seventy six percent of the logging workforce had at least one training module (Byers, 1995a). The logging workforce is predominantly male, with only 1.5% of the workforce being female (Byers pers.comm, 1996). The logging workforce is comprised of two major ethnic groups consisting of 57% European and 41% Maori. Unlike the silviculture workforce, where Pacific Islanders accounted for 9% of the workforce, in logging they only accounted for 1.5% (Byers, 1995a).

1.3 Future Developments

Traditionally, employment within the timber harvesting sector of the forest industry has contained a significant component of manual work. More recently this started to change with the development of technological advances which enable the partial or full mechanisation of certain harvesting tasks. Many overseas forestry nations have mechanised a large proportion of their timber harvesting and processing operations, particularly in Scandinavia and the United States. Such moves have been assisted by available and appropriate technologies, favourable timber resources, agreeable topography and most importantly, the emergence of critical health and safety issues.

New Zealand's forest industry, while beginning to mechanise, still requires a large contingent of manual labour in order for it to function effectively. This will continue to be the case for the foreseeable future due to a relatively large proportion of the timber resource being established on steep and inauspicious terrain, and economy of scale constraints associated with the large production rates generated by mechanised operations. Nevertheless, timber production from New Zealand plantation forests has consistently increased over the last decade. In 1988 2504 logging workers produced 9,688,000 m³ of timber. By 1994 the logging workforce had increased to 3369 and production to 15,937,000 m³. In relative terms this means that in 1988 each person employed in logging produced 3,869 m³ of wood per annum. By 1994 this had increased to 4,730 m³ per annum. Whilst some of this increased production would have been generated through the use of better technologies and increased production due to mechanisation, the majority can still be attributed to increased use of motor-manual systems, that is, a person using a chainsaw.

1.4 Manual Forestry Work

Manual forestry work has been categorised by many researchers as an occupation requiring moderate to heavy physical workloads (110-145 bt.min⁻¹), high rates of energy expenditure (7.5 - 10.0 kcal.min⁻¹) and oxygen consumption (1.5 - 2.0 l.min⁻¹) (Cristofolini et al., 1990; Fibiger and Henderson, 1982; Hagen, 1993; Harstela, 1990;

Henderson, 1984; Kirk and Parker, 1994b; Kukkonen-Harjula, 1984; Parker and Kirk, 1994; Seixas and Ducatti, 1995). Such work is often undertaken in inhospitable working environments, and in close proximity to potentially dangerous equipment and situations (Golsse and Rickards, 1990; Vik, 1984). The hazardous nature of the fallers work requires constant vigilance in order to prevent serious or fatal injuries from occurring. A multitude 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 misread, neglected or incorrectly diagnosed, then the result for the forest worker can be serious injury or death.

This has been the case with forest harvesting operations globally. Similar research findings have been found in Scandinavia (Hagen et al., 1993; Kukkonen-Harjula, 1984), Europe (Van Loon, 1976), United States (Johnson and Tabor, 1987; Smith and Sirois, 1982; Smith et al., 1985; Smith et al., 1986; Smith and Thomas, 1993), Canada (Robinson et al., 1993; Trites et al., 1993), South America (Apud et al., 1990; Apud and Valdes, 1993; Apud and Valdes, 1994; Seixas and Ducatti, 1995), Asia (Andersson, 1986), Africa (Abeli and Malisa, 1994), Australia (Henderson, 1984) and New Zealand (Gaskin, 1990; Kirk and Parker, 1993a; Kirk and Parker, 1994b; Kirk and Sullman, 1995; Parker and Kirk, 1993b; Vitalis et al., 1986) to name a few.

Most of New Zealand's 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 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* (Parker, 1991; Parker and Kirk, 1993b; Tapp et al., 1990), *accident type and frequency*, (Gaskin and Parker, 1992; Parker, 1994; Parker, 1995; Prebble, 1984; Slappendel et al., 1993), *physiological strain* (Gaskin, 1990; Kirk and Parker, 1993b; Kirk and Parker, 1994b, Kirk and Sullman, 1995; Parker and Kirk, 1993a; Vitalis et al., 1986;), *biomechanical loadings* (Gaskin, 1990; Gaskin et al., 1987; O'Leary, 1988), *socio-political factors* (Byers, 1994; Byers, 1995a; Byers, 1995b; Byers and Adams, 1995; Gibson, 1994) and *the role of personal protective equipment* (Kirk,

1992; Kirk, 1993; Kirk et al., 1992; Kirk and Parker, 1994; Prebble, 1981; Sullman, 1994) associated with forest harvesting operations.

However, the majority of these studies have traditionally utilised one single measure to determine the physiological or mental effort being exerted by the person undertaking the observed task. The work undertaken by Kirk and Parker (1994b) investigating the physiological workloads experienced in several sectors of the forest industry, gave an insight into the severity of workloads experienced by forest workers in New Zealand. The research by Kirk and Sullman (1995) took this work a step further and used a series of measures to determine the impact of physiological and psycho-physiological stressors on the safety, comfort, productivity and fatigue of hauler breaker-outs.

The objective of this thesis is to develop this research further by applying heart rate indices and subjective questionnaire protocols developed by Kirk and Sullman (1995) to motor-manual tree fallers in an attempt to determine fatigue in forest workers.

1.5 Summary

This chapter briefly outlined the history of plantation forestry in New Zealand, its resource and labour force. It then examined the current and future labour requirements for the industry. Past and present ergonomic research relating to manual forestry work in New Zealand was examined Chapter 2 identifies key issues pertaining to fatigue and reviews past and present research pertinent to each of these issues.