ERGONOMICS OF TREE PLANTING WORK AMONG BRITISH COLUMBIA FOREST WORKERS

by

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Abstract

Little objective data exist characterizing the ergonomic demand of tree planting work although a substantial number of workers are seasonally employed in the industry each year in British Columbia. The purpose of this study therefore was to determine the ergonomic factors of the job and analyse the variation in physical, physiological, biochemical, and health indices of a group of tree planters who were periodically assessed in a field camp throughout a planting contract period. Sixteen British Columbia reforestation workers were studied during their employment on a tree planting contract throughout a total period of 75 days. Their work was organizea in shifts of about five days on and one or two days rest. Each worker was studied on the first day of each work shift and data were collected on each in the morning upon their awakening and again in the evening upon their return home from work. A blood sample was taken from a subject on each of these occasions. A simple health questionnaire was completed once per day. Throughout the day a subject's heart rate was continuously monitored and their work habit videotaped. Blood samples were later analyzed for cortisol, elevated serum muscle enzyme activity (ESEA); creatine kinase (CK), Lactate Dehydrogenase (LDH) and asparate serum transferase (AST), and blood hematology parameters (BH), hematocrit (Hct), red blood cell (RBC), and hemoglobin (Hgb).

Camp organization, worker health, and work time distribution was analysed from the questionnaire and videotape records. The mean working heart rate of the tree planters studied was 117 $b \cdot min^{-1}$ (range 100-139). This rate was sustained throughout an 8.0 hour day and represented 39.2% of the age predicted maximum above a resting baseline heart rate (ΔHRratio). Serum cortisol concentration

showed a significant variation among sample day means for only the pre-work measure (ANOVA, $p \le 0.05$) and indicated a slight decreasing trend during the planting period. The remaining blood data were analyzed for each sample day only for a subset of planters ($n=10$) of the original 16, who survived throughout the whole planting period. Pre- and post-work ESEA of these workers were both significantly higher on each sampling occasion throughout planting period compared with a pre-season resting control group ($n=9$, $p \le 0.01$). The difference between the pre- and post-work serum concentration of CK and AST decreased in most workers during successive weeks of planting as they adapted to the work routine. LDH continued to rise however and remained significantly elevated on the last sample day of the period (day 32) compared with the first day. A decreasing trend in BH parameters was observed during the period, which did not however become significant. Pooled blood data from all subjects for the whole period showed a highly significant difference ($p \le 0.01$) between pre- and post-work samples for all BH parameters as well as ESEA (BH parameters decreased and ESEA increased). These data suggest that the the work/rest schedule practiced in the camp under study was not optimal, producing incipient debilitating changes that may have compromised a worker's well-being and productivity.

Dedication

I would like to dedicate this work to the memory of Henry Brownrig, a tree planter for many years, and an active member of the Pacific Reforestation Worker's Association. His work and advocacy toward the betterment of working conditions was integral to the commencement of scientific study reflecting the concerns of tree planters.

Acknowledgement

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Introduction

Reforestation activity in British Columbia's silviculture industry is notoriously taxing work requiring long days, a high daily rate of repetitive work, and life in a remote camp. With the current trend towards increasing the annual number of seedlings planted in British Columbia (BCMOF 1986) and with little future possibility for mechanization of the planting task (Stjernberg 1988), tree planting is likely to remain a labour intensive occupation for many years to come.

Central to any future success of the tree planting industry will be its demonstrated capacity to replant and manage forests expeditiously after logging. The magnitude of the reforestation task is enormous. An estimated 3.8 million hectares of crown land in British Columbia have not been sufficiently restocked. Another 2.5 million hectares are over-stocked, densely planted and require spacing. An unknown area of poor performance plantations resulting from competitive growth of surrounding vegetation, brush, and poorly adapting nursery seedlings also needs reclamation (BCMOF 1986).

Optimal planting productivity and quality control of the work requires an experienced individual with good visual-manual coordination and judgement, coupled with a high level of motivation and commitment (Smith 1987). However, the human resource requirement to meet this burgeoning silviculture effort has received comparatively little attention and is of concern (Silviculture Joint Adjustment Committee Report (SJACR), 1988). The Pacific Reforestation Workers Association (PRWA) estimates an average annual turnover of 50% of tree planters in a work force of some 10,000 full time workers. In some regions this turnover is as high as 80% (PRWA, personal communication). In a recent

survey (SJACR 1988) planters, when asked their reason for leaving the industry, gave as their primary reason (79% of respondents) "the work was too physically demanding".

There is considerable subjective observation, collectively voiced by the Pacific Reforestation Workers Association (PRWA), indicating that tree planting is often dangerous and physically debilitating and may leave a worker very fatigued at the end of a planting season.

Smith and his co-workers (1987) initially drew attention to the occupational characteristics of tree planting work. They showed tree planting presented persistent health, safety, ergonomic, and organizational problems which lead to an uneven quality and productivity of work, occupational stress, and an unacceptable rate of labour turnover. An occupational health and safety questionnaire indicated a planter's annual risk of injury from accidents was as high as 75% and often resulted in multiple injuries. Giguere *et al.* (1991) found one out of two tree planters sustained a work related accident or injury during his or her planting career. Silviculture workers work under a piece rate payment structure, often up to 60% of their maximal aerobic power (Smith 1986). A pilot study carried out in 1988 (Banister *et al.* 1990), indicated the work intensity of a tree-planter ranged between 40% and 70% of their maximum $\dot{V}O_2$, sustained for a total of 7.5 hours per working day. A health questionnaire response, serially administered, revealed frequent symptoms of fatigue, irritability, muscle weakness, and depression in the work force throughout a planting season.

A global term, "burnout", is often used to describe a reforestation worker's physical and mental attitude at the end of a planting season but this is currently more a qualitative, rather than a precise scientific label. A diverse range of altered physiological, biochemical, and clinical parameters characterizes a similar

syndrome known as "over-training" or "staleness" in athletes (Kuipers and Keizer 1988; Barron *et al.* 1985; Ryan *et al.* 1983; Mellerowicz and Barron 1971). However "burnout", which causes debilitation, sickness and under-performance in the tree planter has received little corresponding physiological or biochemical characterization.

Thus it is important to measure this phenomenon, albeit under the rather alien scientific conditions of camp life, and to obtain data describing various biochemical, physiological, and ergonomic characteristic responses to reforestation work.

General Approach

The goal of the present research was to extend previous studies by serial quantitative measurement of the effect of tree planting on a worker's changing physical, physiological and biochemical characteristics during a planting season.

This investigation focussed on:

i)   measuring energy expenditure during planting,

ii)   documenting the physiologically demanding nature of tree planting work from the serial change in work-induced change in his or her elevated serum enzyme activity (ESEA) and hematological variables throughout a season's planting activity,

iii)   developing a coherent theory of the phenomenological descriptive term "burnout" and attempting to determine the pattern (time course) of its development by serially monitoring changes in serum concentrations of cortisol, and ESEA.

Serial physical, physiological, and biochemical responses to the strain of daily tree planting work of a group of tree planters were measured and analysed during a seasonal period. Ten visits to an established camp were made from May 10, 1989 to July 23 1989. During each visit the following measurements were taken from each planter volunteering his or her participation:

i)   pre- and post-work blood chemistry,

ii)   working heart rate and measurement of cardiovascular fitness ,

iii)   completion of a daily diary of work-rest activity and a health questionnaire check list. Video tape of actual work phases were used to provide some visual confirmation of the appropriateness of the physiological measurement.

Chapter 2   Literature Review.

Current silviculture work practice, working conditions, and camp conditions in tree planting operations in British Columbia are described in this section and related to the identifiable stressful condition of the work. Exercise, sport, and occupational studies of animals and human have long contained important insight into the biochemical and physiological correlates of chronic and acute stress and the literature on these studies is also examined in this chapter.

I. Silviculture in British Columbia

Background

Both tree planters and contractors of tree planting work are largely unorganized in the silviculture industry. Contractors may belong to the Western Silviculture Contractors Association, while some planters are members of the Pacific Reforestation Worker's Association. The planting season usually begins in February on coastal sites and migrates inland as snow melts in the early spring. The average length of work each year is about 12 weeks. A study of the economic and social impact of tree planting in British Columbia, (Canadian Forest Service 1987), shows the income from this short employment period to average between $6,000 and $7,000 per year and account for, on average, 70% of the annual income of a planter. Seventy percent of workers were less than 30 years old, more than one third were students, and nearly one quarter had obtained at least one university degree. Seventy percent of workers had previous tree planting experience while 52% had 3 or more years experience. An estimated 1700 workers

were employed during a planting season of whom 37% were hired locally at the contract site and 85% were from British Columbia.

A labour contractor once having obtained a planting contract, either as a result of a low bid system or the more recent "preferred bid" system, assembles a crew of workers and provides lodging in a make-shift camp near a remote work-site. The contract specifies the area to be planted, the density of the planting, and the specific time frame for the start and completion of planting activity. The camp usually includes a large floorless dining tent (which doubles as a social centre), a kitchen, a drying tent, and a shower tent. For the most part, a worker lives in his or her own tent and is provided two hot meals per day (breakfast and supper), and transportation to and from the work site.

Camp Standards

Camp standards have improved gradually each year in response to minimum standards imposed by both the Ministry of Health and the Workers' Compensation Board. These include mandatory refrigeration, proper food storage facilities, wooden floors in the dining tents, provision of drying rooms, and a requirement for a minimum number of out houses and showers, according to camp numbers. The long term goal is to provide food handling and hygiene standards in these camps on par with standards set in the catering and restaurant industry.

Current camp conditions can be a source of stress for the worker. Workers are concerned about maintaining hygienic conditions and improving camp comfort, yet despite recently legislated minimum camp standards the camps are still poorly regulated by the Ministry of Health. In addition to not meeting Ministry of Health's camp standards, many camps still lack a reliable source of

heat, have poor lighting, too few showers, with low water pressure, inconsistent water flow and temperature, and substandard tent accommodation. In addition, interpersonal stress (due to continuous living and working with the same people in the absence of home comfort and limited private indoor space) is evident in some workers and needs to be considered in the ongoing health standard evaluation of camps. In the interim, each camp and location has unique characteristics which need to be adapted to and each individual must develop their own strategy for coping with camp life.

Description of work

A planting contract lasts from several days to several weeks. Each planter works a sub-area (approximately 1 hectare) of each day's group allocation, and is given the spacing requirement between trees. The tree planter has to cover the planting area following a strategic plan to ensure even distribution of planted seedlings.

Trees are carried in three hip bags, evenly balanced, and secured around the hips with the additional support of shoulder straps. A bag weighs between 10 and 20 kilograms at the beginning of a planting run, loaded with 300-400 seedlings. A D-handle or staff handle shovel (1-3 Kg) specifically designed for planting seedlings is used. Planting quality standards require seedling roots to be planted in mineral soil with straight roots and soil sufficiently compacted. Spacing between planted seedlings (1.4-2.5 m), and the size of the area to be left surrounding the seedling, which must be cleared of all non-mineral organic material (0.1-0.3 m), are all specified.

A great deal of repetitive work characterizes the task. For each tree planted a typical cycle requires the planter to:

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i) visually appraise the site within the spacing requirement in order to judge where optimal conditions for seedling survival are compatible with ease of planting,

(ii) clear the organic biomass by boot kicks or with a shovel to expose mineral soil,

(iii) loosen the soil and open a hole with the shovel in preparation for taking a tree from a hip bag for planting,

(iv) bend at the hip and insert the tree in the prepared site ensuring straight roots,

(v) close the hole with surrounding earth using a shovel and a foot stamp to firm the surrounding soil, ensuring no air pockets.

This cycle of operation takes between 5 and 60 seconds to complete depending on:

i) the site preparation layout and complexity of the terrain,

ii) the planting quality standard maintained,

iii) the skill of the worker.

Thus individual productivity ranges from 300 to over 3000 trees per day. The planting terrain may be steep, rocky, and hard packed. It may also have a thick layer of organic material (duff) that has to be manually cleared, and may be covered to a varying degree with bedrock, surface water, logging slash and non-merchantilable logs. A planter may take up to three seasons to achieve a competent level of planting skill in British Columbia's diverse and rugged terrain (PRWA, personal communication). A planter must not only endure strenuous working conditions but in addition must resist the continuous assault of bugs, soot, dust, heavy slash, cold, heat, rain, wind, and sun.

Physcial work intensity

Silviculture workers work under a piece rate payment structure, often up to 60% of their maximal aerobic power (Smith 1986). An occupational health and safety questionnaire indicated a planter's annual risk of injury from accidents was as high as 75% and often resulted in multiple injuries. Giguere *et al.* (1991) found one out of two tree planters interviewed reported having a work related accident or injury during his or her planting career. The most common body parts injured were the knee, foot, ankle, skin, eyes, and the wrist. The cardiovascular heart rate response during a planting observation period averaged 122 ± 19 $b \cdot min^{-1}$. Mincheva *et al.* (1986) studied manual site preparation and tree planting operation in 21 female Belgium tree planters. Maximal aerobic power was determined prior to measurement of a field HR measure. The resulting aerobic demand for tree planting work was classified as moderately high by the author.

Relative to guidelines given in the literature for a sustainable maximal daily work rate (Wells *et al.* 1957), the intensity of tree planting work may be classified as heavy to very heavy labour. The high work rate measured during the planting work suggests that tree planters are under pressure to work harder than a freely chosen work intensity. A worker, when free to set his or her own pace of work, chooses a physical work intensity of between 30% and 45% of $\dot{V}O_2max$ (Astrand 1967; Evans *et al.*, 1980). Work exceeding 40% of $\dot{V}O_2max$ for eight hours leaves residual tiredness in a worker at the end of a day and throughout any evening leisure period (Astrand and Rodahl 1986) and results in a slowly accumulating long term fatigue.

Piece work

Presently British Columbia tree planters are paid for each tree they plant (piecework). Tree prices are set in a highly competitive industry by contractor bids on variably priced planting terrain. A tree price is established based on an estimated difficulty of the terrain to be planted. This determines the planting rate for each contract which may change frequently. A silviculture worker's daily wage thus may vary from day to day depending both upon the number of trees he or she is able to plant on the immediate terrain, and on the price paid per tree. Piecework payment encourages an increased production by the worker by stimulating a high aerobic work rate with concomitantly few rest pauses and an overall sense of urgency.

Planters are paid only for work directly related to planting activity. Workers are not paid for travel time, seedling portages, seedling stash management, camp set up or take down, or camp chores such as washing dishes or operating pumps and generators. There are also numerous unforeseen events outside a worker's control such as seedling delivery delays, transportation delays, (flat tires, impassable roads due to washouts or inadequate maintenance, mechanical failure), inclement weather, contract start delays, contract cancellation, and others. Such unforeseen events are unpaid and may last from several minutes to several weeks with a minimum of notice. In addition numerous occurrences of non-payment, quality fines, and payment less than promised by the contractor have been reported to the PRWA and the Silviculture Joint Adjustment Committee (SJACR 1987). Anxiety over one's daily pay, especially during completion of a contract which has been underbid by a contractor, can be a significant source of stress during the planting period for some individuals.

Piecework is highly favored among silviculture workers in the industry. In a survey (SJACR 1987), of 115 planters, only one individual complained about the piecework system of payment "Pay not worth it" was only cited a few times as the reason people leave the industry , while "the pay is good" was the most frequently mentioned reason why people stay in the industry.

A monetary incentive may strengthen the motivation for work, and increase an employee's focus, intensity and endurance. Stjernberg (1988), compared productivity between groups of Ontario silviculture workers paid either an hourly wage or on a piecework basis. Not surprisingly, hourly paid planters spent nearly twice as much time on non-productive activities (26.1%) compared with those on piece-rate (12%). Measurement of the time spent in the specific activity of planting (walking, planting, bag filling) showed that the only difference between these groups was in the percent of time spent planting (63.3% for the hourly worker, 71.4% for the pieceworker). Piecework also seemed to encourage faster planting as the mean planting speed in the two groups was 5.6 sec/tree and 5.2 sec/tree respectively. However the group number on which this measurement was made was small (n=6).

Piece work and stress in other occupations

Evidence from other occupational studies suggests piece work contributes to stress by increasing plasma catecholamines (Timio and Gentili 1976). Timio and Gentili (1976) showed a significant increase in plasma epinephrine (E), norepinephrine (NE), and 11-hydroxycorticosteroids in assembly line workers under a piecework payment scheme compared with salaried workers and ordinary hourly-paid workers. In another study, Johansson (1981) found quantitative, but not qualitative performance improved during a partially paced repetitive/choice

reaction task. Levi (1972) reports many piece-rate workers are constantly tired, and physically uncomfortable and have an increased feeling of too little time to complete a task compared with non piece-rate workers.

Consideration of these negative aspects leads to the conclusion that, piecework may encourage a lower occupational health standard, due to the fact that a liberally paid piece-work employee is apt to overwork, and increasingly jeopardize his or her health and constitution in a very few years.

Summary

Studies to date describe tree planting as a labour intensive occupation which poses a distinct risk to worker health and safety (Smith 1987; Giguere *et al.* 1991). The combination of a short planting season, coupled with a piecework payment scheme, and life in remote makeshift camps, encourages long work shifts and a hastened pace of work. Such a work ethic may precipitate the 'burnout' syndrome as it has been described within the tree planting community.

II Stress response

Tree planting has often been described as a 'stressful' occupation. The term 'stress' can have several interpretations and requires a precise definition. That emotional, mental and physical aberrations which result in a change in the internal milieu or homeostasis of the body have been well described in the literature (Cannon 1915; Seyle 1946). The response state within the body to external stressors is also generally termed stress. Stressors are defined as all environmental, physical and psychological stimuli eliciting a measurable deviance from homeostasis within any given physiological system. Stress mechanisms have been described by Selye (1956), who referred to stress in terms of

eustress and distress. Such terms describe stress as having either a positive or a negative effect on the body. Eustress is characterized by a return to a pre-stress baseline measure of stress some time after an excessive stressor is removed. Eustress has an adaptive value necessary for the development and survival of the organism. Distress results from chronic unrelieved stress, where an accumulation of negative consequences on the body result in homeostatic changes. Impaired function of any of the constituent body organs is the end result of distress, whereas mild stress (eustress) allows adaptation and an ability to tolerate a higher intermittent stress.

Chronic stress is defined as an habitual stress response sustained during several days, weeks or years. The cumulative daily stress due to several weeks of tree planting work will also be defined and referred to as chronic stress. When a workrate is too great and recovery and adaptation do not occur before the beginning of the next work shift the term 'over-working' may be used to describe a condition of diminished or dysfunctional response to the continued stress. Environmental, physical, emotional and psychological factors may also contribute toward staleness. Cumulative stress due to training, poor environmental surrounding, over-work, and personal problems may exceed an individual's capacity to cope (Seyle 1976). Such a state can be induced through persistent devotion to a goal which may or may not provide a rewarding experience (Veale 1991). Fear of failure, excessive expectations from an employer, and competitive athletic demands are some sources of intolerable stress (Costill 1986). Work monotony, and personal and emotional demands from work or perceived authority also often precede staleness (Israel 1976; Keretszty 1971). Staleness may reflect the serious stage of exhaustion described in Selyle's General Adaptation (GAS) Model (Selye 1946).

The biochemical stress response in the body is commonly said to involve the so-called sympathetic-adrenomedullary axis (SA-axis) and the hypothalmic-pituitary-adrenocortical axis (HPA-axis) which serve to enhance the circulation of catecholamines and glucocorticoids respectively. Typical indicators of such biochemical response to stress is the increase in plasma norepinephrine (NE), epinephrine (E), cortisol (COR) or corticosterone concentration (Axelrod and Reisine 1984). NE and E are released by sympathetic inervation of the adrenal medulla and cortisol is released from the adrenal cortex via pituitary ACTH, which is mobilized by the release of a hypothalamic neurohormonal factor (CRF). The main action of the catecholamines are to increase the heart rate, and myocardial contractility, dilation or relaxation of smooth muscle, and increased glucogenolysis, lipolysis, and inhibition of insulin. The main actions for cortisol during stress are increased lipolysis, proteolysis, and glycogenolysis. The correlation between NE release and its' increased circulating concentration with an increased degree of sympathetic activity is evidenced by study of electrical stimulation of sympathetic nerves leading to various end organs and from the study of postural changes (De Quattro and Chan 1972; Euler 1974; Lake *et al.* 1976; De Champlain *et al.* 1976).

The increase in secretion of cortisol, NE, and E concentration above the normal circadian rhythm value induced by stress may be specifically related to the different nature of physical and psychological stress (Selye 1956). Psychological factors such as anxiety or the degree of personal control perceived to be held in a task, the initial behavioural response to a novel situation (Selye 1956), or the response to exercise of sufficient intensity or duration (Viru *et al.* 1992), are all considered to activate the HPA-axis. Physical work of even a moderate degree

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stimulates the SA-axis and is indicated by an increase in blood and urine catecholamine concentration (Euler 1969).

Other biochemical and physiological systems are affected by stress and this is indicated by cellular enzyme leak to the vascular space (ESEA) in response to direct physical trauma to the musculature (Noakes 1987), a decreased blood haemoglobin, red blood cell and haematocrit (Magnusson *et al.* 1984). and suppression of the immune system (Locke 1982 ; Borysenko and Borysenko 1982).

III Measurement of chronic stress

While a great deal of research has been carried out in the last 80 years on the stress response of an organism there is surprisingly little work published on long term or "chronic stress" (environment or lifestyle). Selye's general adaptation syndrome (GAS) model predicts an exhaustion of the stress response following a period of chronic stress. To date empirical evidence for this GAS model has been inconclusive yet prospective studies studying chronic stress have shown variable changes in the stress measures.

SA-axis under chronic stress

The literature shows an increase in resting catecholamine concentration under conditions of chronic stress. Prolonged chronic stress may induce a persisting increase in resting plasma catecholamine concentration following termination of the stress. Plasma catecholamine concentration (both NE and E) has been shown to increase under both stressful conditions and at rest in addition to exhibiting a normal diurnal rhythm. Cleroux *et al.* (1985) measured the acute elevation of blood catecholamine concentration following an exercise bout in humans and found that almost four hours were required to re-establish the basal

value. In a group of swimmers who doubled their training mileage a pre-exercise resting plasma E and NE concentration increased (though not significantly) by the end of a 10 day training period (Kirwan *et al.* 1988). An elevated plasma NE concentration has also been observed in athletes for up to 4 days following the chronic stress of a marathon run and E was elevated for one day post-marathon (Maron *et al.* 1977) .

Following a forced swimming stress in rats, the 24-hour urinary adrenaline concentration remained elevated for at least 2 days after swimming, whereas the light phase E excretion was high for almost one week post-stress (Sudo 1988). This suggests that recovery from swimming stress can take more than 2 days reflecting an ongoing hyperactivation of the sympathathetic-adrenomedullary system (SA-axis).

A recent investigation has shown decreased SA-axis activation during a stressful training regime. During a prospective study of middle and long distance runners who increased their training volume 100% during a four week period the nocturnal urinary excretion of free catecholamines was constant during the four week period but decreased markedly thereafter to 48% NE and 52% E of their earlier excretion rates (Lehman *et al.* 1992). The measured decrease corresponded to an observed decreased maximum performance ability in the athletes. They complained of stiff muscles, total exhaustion, fatigue and burnout. In a control group practising a more moderate training program in the same study only a marginal decrease in nocturnal free catecholamines, improved endurance performance, and a significantly lower complaint index was noted for the group.

The physiological significance of the continued post-stress SA-axis activation is not clear. One explanation may be that adrenoceptor desensitization is involved in the process of recovery from a stressful stimulus. Yanaguchi *et al.* (1981)

showed subsensitivity to the cardiovascular effects of adrenalin following a repeated immobilization stress.

A post-stress continued elevated catecholamine excretion demonstrates that recovery from stress is an important measure in any evaluation of the residual effect of stress and may be a valuable indicator of over-work. Measurement of biochemical and physiological parameters in the resting condition may then be useful indicators to test post-stress effects of a working environment. Prolonged over work during several weeks of tree-planting work may result in a similar gradual inhibition of the SA-axis activity.

Hypothalamic Pituitary Adrenocortical Axis

HPA activation and physical work intensity

The exact metabolic role for an increase in serum cortisol concentration during exercise remains equivocal yet an elevated serum cortisol concentration during exercise has been found to accompany an increasing or prolonged exercise stimulus which depends also on an individual's state of training (Viru *et al.* 1992; Tharp 1975). A critical threshold work intensity (60% $\dot{V}O_2$ max) seemed to be needed to induce a serum cortisol increase (Davies and Few 1973). Short term exercise of moderate intensity has no effect on the cortisol concentration in fit subjects although a progressive rise in plasma cortisol concentration has been reported among unfit subjects during moderate to intense exercise (Sutton 1978). When the cortisol concentration is elevated during exercise, a return to a basal level requires 2-3 hours (Sundsfjord *et al.* 1975). Using a cohort of 82 subjects in a 2 hour continuous cycle ergometry protocol at 60% $\dot{V}O_2$ max Viru *et al.* (1991) reported 5 variants in the dynamics of the cortisol response to moderately intense

exercise. Of 82 subjects, 21 demonstrated a pronounced increase in cortisol concentration only during the second hour of exercise; 36 subjects demonstrated an increase during the first 30 minutes of exercise which either subsided to a basal level (in 16) or peaked again at the end of exercise (in 21); 10 subjects demonstrated a monophasic increase during the whole period of exercise while 15 decreased. HPA activation was more pronounced among the athletes compared with untrained subjects. Twenty four hour post-exercise recovery showed a significant decrease in cortisol concentration compared with the pre-exercise concentration. Viru *et al.* (1991) has suggested that the threshold activation of the HPA-axis is determined both by the intensity and duration of exercise. The exercise intensity threshold occurs at the beginning of exercise and is of a smaller amplitude, whereas the exercise duration threshold is determined after a certain time period and is more pronounced. Tabata *et al.* (1984) showed the HPA-axis was activated during prolonged low intensity aerobic exercise (of between 60 and 90 min duration) as the blood glucose concentration declined below a critical concentration (3.3 mmol/l). This suggests that blood sugar concentration maintenance during glycogen depletion stress may be a primary stimulant for cortisol secretion.

In one study of a group of swimmers who doubled their normal training distance during a ten day period, a significant increase in pre-exercise cortisol concentration was found on day 10 compared with day 1 (Kirwan *et al.* 1988). The post marathon mean cortisol concentration of runners has been reported to be 3-4 times higher than a control value (Dessypris *et al* 1976; Newmark *et al* 1976). A chronic, elevated cortisol concentration following a prolonged work period may delay the onset of any following anabolic phase (Kuoppasalmi and Aldercrectz, 1985), and may inhibit repair and adaptation of the skeletal muscle system.

Sustained elevation of physical work may thus adversely affect adaptation to a chronic stress situation if insufficient recovery time is allowed the organism.

However in another study, post-marathon blood cortisol concentration was depressed for 3 days following a marathon in comparison with a pre-race control, (Maron *et al.* 1977). In one exhausted marathon runner, who retired at the 15 kilometer mark, blood cortisol concentration was greatly depressed compared with the pre-race measure (Dessypris *et al.* 1976).

HPA-axis and chronic stress

Clinical investigation has shown a lower cortisol concentration in a group of patients suffering from chronic fatigue compared with a control group matched for age and sex (Poteliakhoff 1981). Similarly a decreased dose or complete withdrawal of steroids in patients on long term treatment results in a delayed return of normal cortisol secretion and also results in complaints of fatigue, nausea and joint pain from the patients (Henneman *et al.* 1955). The association of fatigue with a depressed HPA-axis indicates that cortisol may exert an important regulatory function on the phenomenon of central fatigue.

A number of recent rat studies have investigated the hypothesis that dysfunction of the HPA-axis is produced during severe or prolonged long term stress. Rivier and Vale (1987) determined a decrease in rat pituitary ACTH concentration and corticosteroid during 3-5 hours of low and moderate foot shocks. These changes were found to be dependent on the intensity and duration of the shock given. Female rats subjected to a 15 day, 8 hour daily immobilization stress showed a steady rise in plasma corticosterone concentration up to day 6 which remaining elevated thereafter during a third week of exposure. A similar increasing pattern in serum corticosterone concentration was shown in rats

following 2.5 hours of daily exposure to stress (Mikulaj *et al.* 1974). Mikulaj *et al.* (1973, 1974) demonstrated that adrenocortical suppression takes 6 to 7 weeks to develop. Viru and Akke (1969) suggest that a decrease in cortisol "is one manifestation of a general defence reaction against a debilitating depletion of the resources of an organism".

Vogel and Jensh (1988) demonstrated that a daily 1 hour exposure to a combined immobilization, noise and light stress for a period of 3 weeks in rats caused:

1) marked individual differences in the degree of stress response,

2) the stress response for cortisol (measured 10 minutes into the trial), to remain constantly elevated (x2 above basal) during the first two weeks of the experiment, and to increase markedly thereafter. Full recovery was evident 3 weeks after the end of the stress condition.

Thus a decrease in serum cortisol concentration seems to be an excellent indicator of chronic stress.

Hypothalamic dysfunction in athletes

Barron and associates (1985) studied HPA-axis function in a group of four runners who had been clinically diagnosed as suffering from the overtraining syndrome. This study established the first known endocrine component to overtraining in human subjects. The over-trained subjects demonstrated a higher resting blood cortisol concentration than the non symptomatic control group runners. In the over-trained a normal cortisol reaction to insulin-induced hypoglycemia, necessary to restore blood glucose concentration, was impaired. An injected supramaximal dose of thyroid releasing hormone showed a normal hormonal response in these athletes. This test suggests a malfunction at the

hypothalamic level of regulation in an over-trained athlete. This observed condition returned to normal following 3 weeks of rest, thus suggesting that the diminished HPA-axis function was temporary.

Overtraining syndrome in athletes

In recent years the mal-adaptation of an athlete to his or her training regime has become increasingly evident (Ryan *et al.* 1983; Lehman *et al.* 1992). When a workrate is too great and recovery and adaptation to it is not allowed before the commencement of the next training regime, the athlete becomes "over-trained" (Kuipers and Keizer 1988). A prolonged imbalance between training and recovery in humans (chronic over-training) leads to a manifestation of physical and psychological symptoms which characterizes and defines the onset of the overtraining syndrome, which has been termed "staleness" (Wolf 1971; Kuipers and Keizer, 1988).

Staleness among athletes closely resembles descriptions of "burnout" or "chronic fatigue" in a work environment where the commonly used term is "over-work".

Over training has been distinguished from muscular overstrain. Muscular overstrain occurs following a periods of prolonged, intense or novel exercise (Armstrong 1984). The resulting muscle fiber damage is reflected in an accompanying increase in serum muscle enzyme activity (Newham *et al.* 1986; Kuipers *et al.* 1983), or an increased plasma urea concentration (Kinderman 1986), which may precede and/or accompany the physical manifestation of staleness (poor performance, apathy, etc.), (Kuipers and Keizer 1988).

Israel (1976) proposed a clinical distinction between a sympathetic and parasympathetic overtraining syndrome. The sympathetic condition is reflected

by an increased sympathetic drive during activity and rest. The parasympathetic condition results from a strong inhibition of the sympathetic system and an increased parasympathetic drive which predominates in both the active and the resting state. Sympathetic symptoms include; increased resting heart rate, a decreased heart rate recovery following exercise, weight loss, insomnia, irritability, anorexia, muscle soreness, and injury. The parasympathetic type of staleness is more difficult to identify. Appetite is usually normal and body weight is constant and the individual sleeps more than normal (Kinderman 1986; Kuipers and Keizer 1988). Psychological symptoms may include feelings of lethargy, loss of motivation, depression and an exaggerated postural hypotension (Ryan *et al.*, 1988). Complete recovery from such a state may take weeks or months (Kuipers and Keizer 1988). Sympathetic system staleness in humans resulting from prolonged stress response may develop into a relative parasympathetic dominance which may result in a reduction in neuroendocrine control. A parallel condition may be evident within the tree planting work regime. While the work rate is typically lower in the tree planter compared with athletes in training, the duration of tree planting work is longer. The piecework incentive also encourages a high workrate, pushing the worker beyond his or her comfort capacity throughout the day.

Elevated serum enzyme activity

An elevated serum enzyme activity (ESEA) following various activity patterns has been the subject of several investigations and reviews. Mild exercise, such as a brief period of walking, effects serum enzyme activity little, while acute, strenuous or less strenuous, but prolonged exercise increases serum activity of lactate dehydrogenase (LDH), asperate serum transminase (AST), and creatine

kinase (CK) (Noakes 1987, Shapiro *et al.* 1973, Noakes and Carter 1982, 1976, Galun and Epstein 1984, Munjal *et al.* 1983). CK activity demonstrates the largest acute change to an exercise stimulus and is a sensitive indicator of skeletal muscle trauma (Clarkson and Tremblay 1988; Noakes 1987; Halonen and Konttinen 1962). For example, a small elevation of CK occurs in an athlete running between 8-16 km (Munjal *et al.* 1983) but this initial elevation increases both as a function of the distance and intensity of running. Serum enzyme elevation in a group of athletes (Noakes and Carter 1976) running 160 km at an average speed of 9 km/hr produced a group mean absolute rise of 1479 U/L in serum CK activity, a level slightly higher than in well trained athletes marching 120 km at an average speed of 6 km/hr (1073 U/L) (Galun and Epstein 1984).

Siegel *et al.* (1980) measured the group mean post marathon CK serum activity in fifteen racers to be 3424 U/L. After the race, CK was significantly elevated amongst the ten fastest runners, compared with the five slowest runners ($p=0.025$). Measured differences in running intensity might account for this.

The common denominator determining the variable ESEA response to exercise is the variable nature of the dose/response mechanism inducing it. Thus:

1. A quantitative dose of training might be expected to induce a quantitative rise in SEA.

2. It is reasonable to assume also that there is also a training response to repeated exposure of muscle to exercise. A repeated dose of of equal quantity exercise on successive occasions has been observed to produce a smaller ESEA effect (Misner *et al.* 1973; Roxin *et al.* 1984; Sanders and Bloor 1975; Buyze *et al* 1976).

3. The ESEA level returns to a baseline level within several days after a single dose of exercise depending on the severity of the single stimulus. For exertion that results in muscle soreness,the return to baseline takes somewhat longer (up to 10 days) (Clarkson *et al.* 1986; Noakes 1987).

4. A male exhibits a higher ESEA elevation to an acute exercise stimulus than does a female (Shumate *et al.* 1979) .

5. Individuals of equal fitness show a variable amount of CK release for the same degree of exertion.

Arkko *et al.* (1983) studied the effects of whole-body massage on enzyme activity. One hour total body massages were given to nine healthy male subjects. A significant elevation occurred immediately after massage, and a peak CK and LDH level of 452 and 411 respectively for each appeared 24 hours after massage. A normal exponential decay of ESEA follows from each peak of activity during recovery from the stimulus. Conventional muscular massage may be considered a form of "passive" muscular loading. Thus, ESEA cannot be exclusively attributed to an oxidative metabolic stress.

Muscle necrosis occurs following physical stress. This is well established and has been shown to have a particular time course during the period needed for regeneration of injured muscle (Kuipers *et al.* 1983; Warhol *et al.* 1985; Friden *et al.* 1983; Karger 1986). The latent pattern of increase in serum CK activity following an eccentric contraction leading to delayed muscle soreness (Newham *et al.* 1986), is correlated with the extent and time course of damage to the fibers. A variation in serum CK activity is also correlated with the relative loss and re-attainment of strength following acute eccentric contraction exercise. Initial strength returned after 96 hours in these experiments.

Measured ESEA in tree planters thus may be able to be used to depict the degree of muscular strain in response to tree planting work. Continued elevated ESEA can be regarded as an indication of non-adaptation to the chronic work stimulus.

Exertional Anaemia

Exercise-induced pseudo-anaemia is relatively recently studied and to date knowledge of the condition is limited by the few number of studies conducted, their small sample size and the lack of properly selected control groups. A transient anaemia may be evidence of a favorable adaptation in which an increased plasma volume is induced will reduce the peripheral vascular resistance to blood flow, resulting in a potentially better oxygen delivery to the tissues (Convertino 1991). However an unfavorable hemolytic anaemia due to actual physical destruction of red blood cells may be a detrimental factor. Mechanical destruction of red cells (Lindeman *et al.* 1978) may originate from impact forces on vascular tissues of the feet and hands during planting operations. A developing relative anaemia may also be attributed to an iron loss in sweat and urine (Hunding *et al.* 1981). Since tree planting has similar attributes to an endurance training regime, the enzyme and hematological trend exhibited by the tree-planting group may result from similar forces. Tree planting work is hard, repetitious, load bearing work involving shovel strikes, foot stamping and jumping from or over logging debris. The sum total of this activity may well account for an anaemic trend during the period of the present study.

Summary

Various metabolic and endocrine parameters have been related in the literature to clinical manifestation of overtraining (over-exertion) or in the relevant case of the tree planter, to burn out. While it has been possible to measure muscular fatigue and some aspects of mental fatigue through measures of decreased physical and mental output, a precise biochemical and physiological explanation of generalized fatigue has been largely unsuccessful. The heavy labour of tree planting, coupled with the piecework incentive and life in a remote and primitive camp during successive weeks of work, may strain multiple psychological, physiological, biochemical and neurological systems ultimately leading to the adverse physical symptoms usually associated with chronic fatigue and stress. The concept that maladapted to life events lead to succeptibility to certain disease states was first put forward by Selye (Selye 1976). Since then a number of human and animal studies conclusively demonstrate that a high degree of chronic stress leads to a suppressed immune responsiveness (Locke 1982, Borysenko and Borysenko 1982). Health problems seem to arise when stress becomes greater than an individual's capacity to cope (Vogel 1985). Such effects are destined not only to impair productivity but also compromise the long term health and safety of the worker, which is in the present case, that of the tree planter.

This literature review has suggested that the most reliable biochemical indicators of such stress are either cortisol or the catecholamines for measuring the endocrine response to stress and ESEA and blood hematology parameters (HGB, RBC, Hct) for measuring physical and cellular stress.

Chapter 3

While a great deal of research to date has characterised the stress response of an organism relatively little work has been published on "chronic" stress associated with "outside" production workers especially in the silviculture industry. In the present study, the cumulative stress induced during several weeks of daily tree planting work might well result in the consistently observed so-called "burn-out" condition of the tree planter. However, the accompanying physical, physiological and biochemical correlates of long term stress in these production workers has not been previously reported and this is the focus of the present study.

Hypotheses

Serially measured biochemical and physiological indicators of stress will change abnormally in response to the continuing stressful activity in tree planters. Specifically in tree planters:

1)   A gradual decrease in the resting endocrine parameter cortisol, which is specifically associated with a diminishing response of the hypothalamic-pipuitary-adrenocortical axis (HPA-axis), will occur.

2)   Post work blood serum enzyme activities of CK, LDH, and AST will be elevated above pre-work measures, and the magnitude of the post-work elevation will decrease during progression of the planting season.

3)   A gradual decreasing trend in the hematological parameters Hct, Hgb, and RBC will occur during the planting season in both pre-work and post-work measures.

4)   Resting physiological measures of Heart rate and Blood pressure will increase during the planting season.

5)   Body weight will decrease from pre- to post work measures and will decrease overall during the observation period.

Materials and methods

Subjects

The subject group comprised 16 volunteers, 13 men and 3 women, who were recruited from a crew of 30 workers hired by a silviculture subcontractor. With the exception of 4 subjects who had been planting for eight weeks immediately prior to the present study, all were at the beginning of their work period. Ten planters averaged 3.6 seasons of prior planting experience (range 1-14), and 6 were novice planters. The group mean age was 26 ±4 yr, (range 18-39) and the group mean weight was 70.9 ±6.7 kg, (range 57-80).

Working conditions

The crew's working season extended from May 10, 1989 to July 23, 1989 in a semi-mountainous region near Revelstoke, British Columbia, Canada, and involved work on four sub-contracts with two camp moves in mid-season. Workers were paid a piece-rate established from the estimated difficulty of terrain to be planted. A planter lived in his or her own tent or trailer and was provided two hot meals a day and transportation to and from the work site in exchange for a daily camp fee. A worker was paid only for trees planted and was not paid for camp set up, take down, travel time, camp chores, or for time lost due to bad weather or incidental work delays. The contractor provided a make-shift camp including a kitchen, dining tent, drying tent, shower tent, wash area and a latrine.

Logistics

This investigation used a repeated measures design. Measurements were taken on 10 occasions throughout a 75 day camp period. Sampling occurred on the first day of each work shift so that one or two days of rest from tree planting followed the previous shift. In this way the acute disturbing effect of prior tree planting work immediately previous to blood sampling was minimized allowing for cumulative effects of the work to be measured.

The intent of the study was not to interfere with work in progress but simply to observe and measure the intensity of the work being performed together with the physical, physiological, and biochemical response of the worker to it. Volunteers signed an informed consent prior to their participation and the work was approved by the university's ethics committee.

Blood chemistry

A portable structure was set up at each site to centralize measurement and sampling procedures. During each visit to the camp during the investigation period blood was sampled in the morning, upon a worker's awakening and once again during the evening upon his or her returning to camp. Subjects were asked to report to the sampling station at their earliest convenience. Approximately 12 hours separated the two sample times. Two blood samples were taken from the antecubital vein. The first sample was immediately centrifuged at 2500 rpm for 10 minutes and the serum separated, labeled, and placed on ice. Serum was analyzed for the elevated serum cortisol concentration and the serum enzyme activity (ESEA) including creatine kinase (CK), lactate dehydrogenase (LDH) and aspartate transaminase activity (AST) respectively. Serum cortisol was measured via radio-immunassay using a kit (Quanti-coat^{Tm})

provided by Kallestadt Ltd. The coefficient of variation ranged between 8.3 and 11% during the period of study. Total LDH and AST activity in serum was measured on a Roche Cobas Bio analyzer at 30° C using Sigma Reagent according to the procedure of Henry *et al.* (1960). Total CK activity (using N-acetylcysteine, activated and optimized to the standards set by the "Deutsche Gesellschaft fur Klinische Chemie") was measured on a Roche Cobas Bio analyzer at 30° C using BMC reagent (Boegringer-Mannhiem CmbH, Mannhiem, West Germany) according to the procedure of Szas *et al.* (1976). The coefficient of variation in repeated daily analysis of a known standard of these enzymes ranged between 3-5% during the period of the study. A second blood sample was collected in a heparinized vial, labeled and reserved on ice for hematology measurement including red blood cell (RBC), haemoglobin (Hgb), and hematocrit (Hct). Hematological measurements were made by standard clinical methods. These two samples were couriered to a biomedical laboratory in Vancouver for analysis within 48 hours of sampling.

An in-season control group (day 0, pre and post work) was obtained from a subset (n=8, 7 men, 1 woman) setting up camp. In addition a pre-season control group was obtained for the ESEA parameters from an independent group of rested planters (n=9, 7 men, 2 women) in Vancouver, during the evening period prior to the beginning of their season.

Measurement of work rate

A personal heart rate monitor, (Polar Electro Finland) was attached to the chest of a planter on the morning of the day of their blood sampling. An FM signal transmitted the subject's heart rate, once each minute, to a memory chip in a watch worn on the wrist throughout the working day. Up to 6 extended

recordings from different planters were collected each measurement day.

Serial working HR data for each planter in the field was converted to an index of maximum cardiovascular strain by expressing the working HR above resting as a percentage of the individual's maximum HR (%ΔHRratio) (Morton *et al.* 1990) using the formula:

$$\%\Delta HRratio = 100 \cdot (HRwork\text{-}HRrest)/(HRmax\text{-}HRrest),$$

where: HRmax = 220-age(yr).

Fitness testing

A physical fitness test was administered on occasion throughout the planting season to the group during the recreational evening period of the day. The physical working capacity was determined from the heart response (using the HR monitor) to incremental work on a Monarch cycle ergometer (Sweden) at three submaximum work rates each lasting 4 minutes. The final work rate was judged to produce a heart rate between 150-160 b·min^{-1} (Sjostrand 1967). A plot of heart rate (b·min^{-1}) against work rate (watts) enabled a prediction of the work rate producing a HR of 170 b·min^{-1} (PWC170) to be made. A similar measure defined as the delta HR 100 was also analyzed from the same work rate data where:

$\Delta HR = HRwork - HRrest.$

$\Delta HR100$ defined the heart rate standard for estimating work rate from the HR/work rate graphical analysis as that which caused elevation of a subject's HR to be 100 b·min^{-1} above resting. This measure effectively eliminated variability of the PWC 170 measure caused by variability among subjects' resting HR (Legge and Banister 1986).

Questionnaire and health data

Each subject recorded general ergonomic and health related data on a daily basis in a personal log book provided. These data included: duration of evening sleep, time of awakening, planting start time, planting stop time, shower time, number of trees planted, number and length of breaks, and health status (response to a series of health questions). The log book pages are shown in appendix A, B, and C.

Statistics

Data were compiled on a Microsoft Excel^{Tm} spreadsheet and were analysed using statsview^{Tm} and systat^{Tm} stastical packages. Data were described generally by a group mean, standard deviation and range for each data set. A two way analysis of variance was used to determine an F statistic of significance between pre and post work group means and between sample dates. A Fisher PLSD test then compared pre and post planting data on different days for a within day difference or between day differences to determine significant comparisons. Significance was determined at the 95% confidence interval.

Results

General

There were 46 planting days during the period, averaging 5 days/week. Shift length averaged 4.5 days, (range 4-7) and days off between shifts averaged 2 (range 1-6). The work-rest cycle followed a 5 day on x 2 days off ratio for the first 3 weeks, a 4 x 1 ratio for the next 3 shifts and thereafter became increasingly irregular. The irregular work-rest cycle was due to contract completion logistics and other complications; including contract completion deadline pressure, the necessity to move camp twice during the season, inclement weather prohibiting work, and on one occasion a two day delay due to late seedling delivery to the camp. Due to the unexpected modification of the crew's contract work indicated previously (camp move, etc.), data were sometimes collected at a time other than the preferred time in the work cycle. The last two planned sample dates occurred on the fifth and sixth days of a work shift and were therefore not included in the blood data analysis. A calendar representation of work, rest, and sample dates is shown in figure 1.

Several subjects were lost to the study, 5 due to their leaving the camp completely and thus ceasing to work, and 2 due to voluntary withdrawal from the study although they continued to work. This attrition rate of 47% left 9 subjects participating at the end of the study. Several subjects did not participate in all aspects of the experimental protocol. For this reason data is analyzed as subsets of the total sample size.

M	T	W	T	F	S	S
May		○ 10	11	12	13	14
15	16	○ 17	18	19	20	21
22	23	○ 24	25	26	27	28
29	30	○ 31	Jun-01	2	3	4
○ 5	Fire Shift Start	7	8	9	○ 10	11
12 Fire Shift End		14	15	○ 16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	Jul-01	2
3	4	5	○ 6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	○ 23
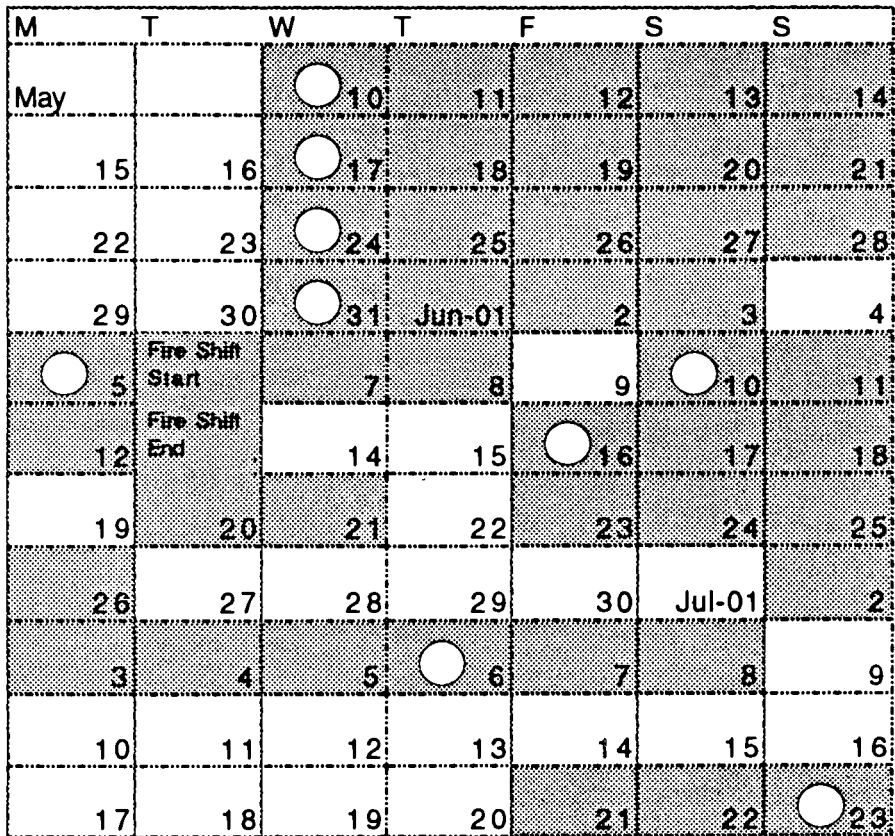
Figure 1. Showing a calendar representation of sample dates (shown as ○) in respect to days worked (shaded region) and days off (unshaded region). A work shift began around 8:00 A.M. and ended at 5:00 P.M. with the exception of the fire shift, (June 6-13) where the shift occurred between 4:00 A.M. and 1:00 pm.

Table 1 shows the general descriptive and anthropometric data for the planting group. Their mean age was 26 ± 4 (SD) years, (range 18-39), and weight at the beginning of the start of the season was 70.9 ±6.7 kg, (range 57-80). The average work experience was 2.5 seasons (range 0-14); 6 subjects had no prior planting experience.

Table 1. Showing anthropometric characteristics and planting experience for the subject group (n=14).

Description	Mean	Range	Std. Dev
age (yrs)	26.2	18-39	6.7
Height (cm)	175	165-185	16.8
Weight (Kg.)	70.9	57-80	6.7
Planting Experience (yr)	2.3	0-15	3.7

The work cycle

A daily activity pattern was determined by averaging all the questionnaire data for each subject and calculating a seasonal representative mean for the group (n=14). The typical 24-hour activity profile is shown in Figure 2. Generally the daily routine was quite consistent. The group mean total work day length (i.e. from the time a worker awoke in the morning to the time he or she returned home, showered and changed clothes) was 12.5 hr. Of this 2.3 hr was spent in pre-work organization which involved dressing, eating breakfast, making a lunch, and being transported to a work site (45 minutes travel time). 8.5 hr was spent in planting activity during which an average of 3 breaks were taken totaling one hour per day. Post-work transport and organizational chores (including showers and changing clothes) took 1.7 hr/day, 3.3 hr remained for dinner and leisure, allowing 8.2 hr for sleep.
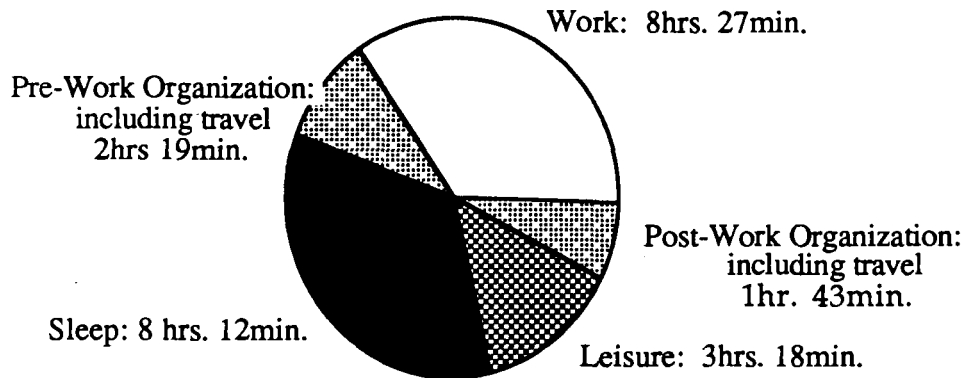
Figure 2.   A 24 hour work day of tree planters representing mean data from all ergonomic questionnaire responses.

Productivity

The group mean productivity for all tree planters during all sample days was 833 ± 363 trees/day (421-1550).   Production was extremely variable due to the varying terrain conditions, the length of the work day and the experience (skill) of the individual planter.

Physical fitness

Thirty-three fitness tests were made on 15 subjects (Ss) during the investigation period (range 1-4 per Ss).   The group mean predicted $\dot{V}O_2max$ (Banister and Legge 1986) was 3.7 1/min.±0.7 (range 2.4 - 4.8).   The group mean PWC_{170} was determined to be 236 ± 53 watts (range 121-309) and the $\Delta HR100$ was 301 ± 54 watts (range 196-399) (Table 2).   The individual fitness score compared with a cross section of Canadian adults, indicate that 8 subjects were above the 95

percentile level, 4 were above the 90 percentile level, 2 were above the 75 percentile level, and the most unfit subject was at the 35 percentile level (Metivier and Orban, 1960).

Figure 2. Fitness characteristics and working HR for the Subject group.

Variable	n	mean	SD	range
$\dot{V}O_2max$ (l·min^{-1})	15	3.7	0.7	2.4-4.8
$\dot{V}O_2max$ (l·min^{-1})	15	51.9	9.9	31-67
PWC_{170} power (watts)	15	236	53	121-309
$\Delta HR100$ power (watts)	15	301	54	196-399
working HR b·min^{-1}	10	117	9	100-139
%ΔHRratio	10	39.2	4	36-60

Working Heart Rate

A working HR record from a group of 10 subjects was collected in total on 47 separate occasions for a mean time of 11.1 hr. on each occasion. To derive a more meaningful daily estimate of a planter's exertional level while actually working, the lower HR values concerned with riding to the work site, rest breaks, light work duties, etc. were cropped from the record to obtain a HR measurement more representative of the response to work performed during 8

hours of planting. An overall group mean HR shows that the group maintained an average HR of 116.5 ± 9 b·min^{-1} during an 8.0 hr work day period. This is equivalent to a mean %ΔHRratio of 39.2% ±4 (range 36-60%). Twenty-four minutes per day were spent at an energy expenditure greater than 60% %ΔHRratio and 61 min was spent at a work rate between 50 and 60 %ΔHRratio. The group mean distribution of minutes-working, at a particular %ΔHRratio for the 11.1 hr and 8 hr work period respectively is shown in Figure 3.
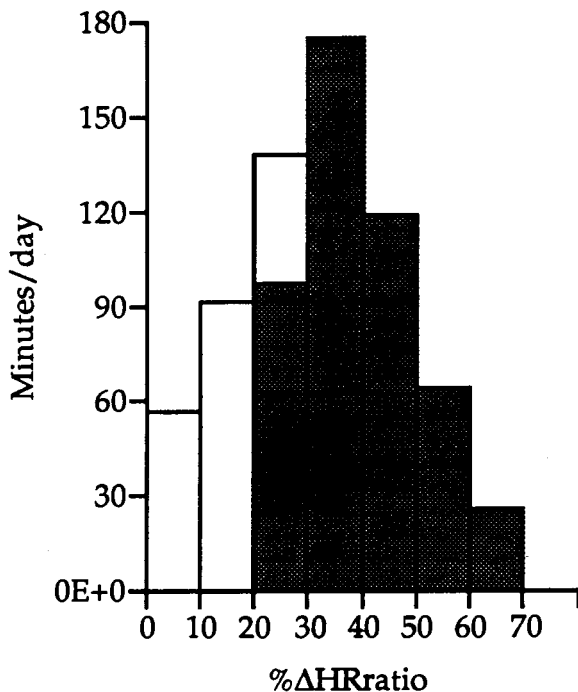
Figure 3. Group frequency distribution of HR as a percentage. ΔHRratio shown for a complete day of recording (11.1 hr) and for 8 hours of specific tree planting work (shaded area).

Paired data were selected from subjects having participated in a work day during which HR was continuously monitored followed by a fitness test that evening. The PWC_{170} statistic was plotted against the %ΔHRratio, (Fig. 4), and a significant relationship was found between an increased fitness and a decreased cardiovascular intensity (HR) during work ($R^2=0.77$, $F_{1,13} = 43.44$, $p \leq 0.05$).
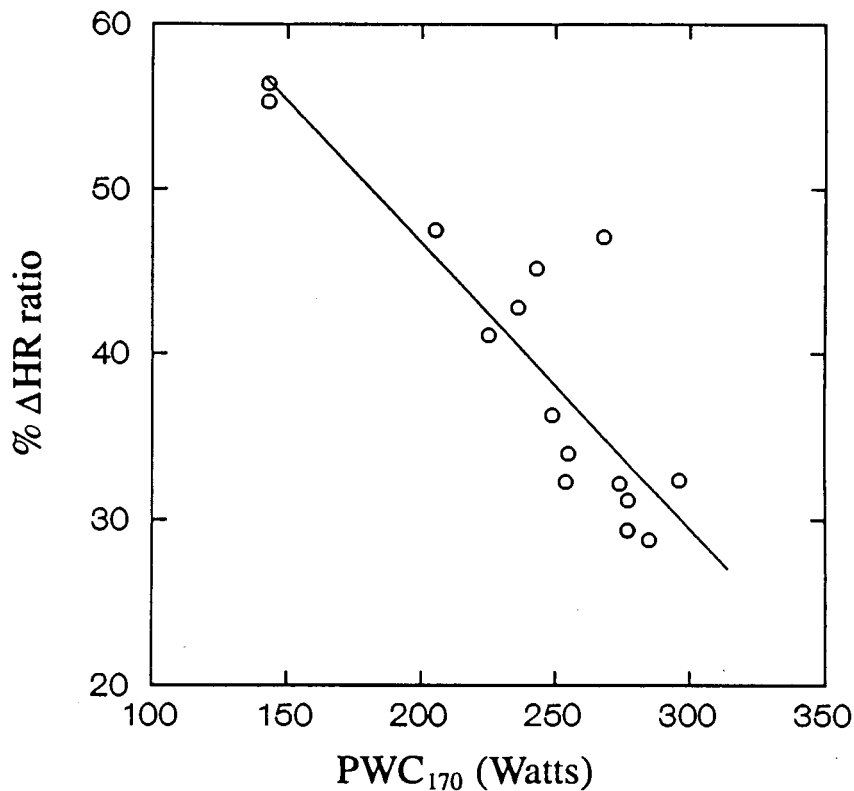
Figure 4. Showing PWC_{170} plotted against %ΔHRratio for those planters participating in a day of HR monitoring and a PWC_{170} fitness test on the same day.

Body Weight

Pre- and post-work body weight was measured on 6 sample dates (Table 3). Most subjects experienced a slight decrease in body weight during the planting period. Subject 16 lost the most (7 kgs), while a few experienced a slight weight gain. There was no significant change (ANOVA f=0.076, p≤0.05) in body weight from one sampling date to the next (6 days between May 18 and July 23).

A pre- to post-work percent variation in body weight was calculated for each subject using the formula

% change in weight = 100 X (Pre-post work weight)/(pre work weight)

Unpaired subject data (pre-post), were deleted from the data set and for subjects with paired data the percent change in body weight is shown in Table 4. A mean decreased body weight of 3.4%±2.7 (range -4.1%-8.7%) for all subjects was determined afor the pre- to post-work period . When pre- to post-work body weight loss was compared for subjects with paired data, there was a net mean daily loss of 2.8 Kg (paired t-test, t_{40} = 8.875, $P \leq 0.05$). Throughout the whole period there was a group mean decrease in pre-work body weight of 1.9 Kg which was not significant (paired t-test, T_{10} = 2.143, $P > 0.05$). Of this group seven subjects lost, three gained, and one showed no change in weight respectively (Table 3).

Table 3. Pre and post work body weight measured on 6 sample dates, showing group averages and individual averages by sample day and by season averages respectively. Also shown are maximal fluctuations of body weight for each subject. An increase (+), or decrease, (-) in body weight during the season is shown in the right column.

pre-work

Ss I.D.	Day 8	Day 22	Day 24	Day 32	Day 58	Day 75	Average	Change
6	61				61		**61.0**	0.0
7	71						**66.0**	0.0
8	59.5	58	58				**58.5**	- 1.5
9	61	60.5					**60.8**	- 0.5
10	80		85	85.5	84	82	**83.4**	+ 5.5
11	73	72	73.5	75			**72.7**	+ 3.0
12	79.5	79	73.5				**77.3**	- 6.0
13		81.5	85	84.5	83.5		**83.6**	+ 3.5
14	72	73	73	73	71	70	**72.0**	- 3.0
15	72	70	73	73	69.5	69	**70.7**	- 4.0
16	84	81	80	77.5	76.5	77	**79.3**	- 7.5
17		73	71				**72.0**	- 2.0
18	74.5	73	75	74	73	72	**73.6**	- 3.0
19			73.5	74.5			**73.5**	+ 1.0
20	66.5	67	65.5	66	63	62	**65.0**	- 4.5
21		77					**77.0**	
pre average	**71.2**	**72.1**	**73.8**	**75.9**	**72.7**	**72.0**	**71.7**	

post-work

	Day 8	Day 22	Day 24	Day 32	Day 58	Day 75	Average	Change
6	60.5				60		**60.3**	- 0.5
7		68.5	66	66			**66.8**	- 2.5
8	57.00	58.00	56.00	54.00			**56.3**	- 4.0
9	59	60.5					**59.8**	+ 1.5
10	80	81.5	81	80.5	82	80	**80.8**	+ 2.0
11	72	71	68	69		66.5	**69.3**	- 5.5
12	76.5	77	76.5	77			**76.8**	+ 0.5
13		79.5	78	77	82		**79.1**	+ 5.0
14		72.5	70.5	69.5	71	68.5	**70.4**	- 4.0
15	68		68	67.5	67	65	**67.1**	- 3.0
16	81.5	79.5	75	76	75	75	**77.0**	- 6.5
17	72	72	70				**71.3**	- 2.0
18	71	71	70	68	73	70	**70.5**	+ 5.0
19	74	73	70	71			**72.0**	- 4.0
20	67	67	60	62	57.5	60	**62.3**	- 9.5
21	76	76.5					**76.3**	+ 0.5
post(avg.)	**70.3**	**72.0**	**69.9**	**69.8**	**70.9**	**69.3**	**69.7**	
pre-post(avg)	**-0.8**	**-0.1**	**-3.9**	**-6.1**	**-1.8**	**-2.7**	**-1.9**	

Table 4. Showing percent decrease in body weight during a planting day for subjects with pre and post-work weights taken. A daily, mean percent loss in body weight is shown for each sample day, (bottom row), and for each individual (right column).

Ss I.D.	Day 8	Day 15	Day 27	Day 32	Day 58	Day 75	Season Avg
6	0.8						0.8
8	4.2	0.0	3.4				2.5
9	3.3	0.0					1.6
10	0.0		4.7	5.8	2.4	2.4	3.1
11	1.4	1.4	7.5	8.0			4.6
12	3.8	2.5	-4.1				0.7
15	5.6		6.8	7.5	3.6	5.8	5.9
16	3.0	1.9	6.3	1.9	2.0	2.6	2.9
18	4.7	2.7	6.7	8.1	0.0	2.8	4.2
20	-0.8	0.0	8.4	6.1	8.7	3.2	4.3
%loss	2.6	1.2	5.0	6.2	3.3	3.4	3.6

Resting Heart Rate

Raw data for pre- and post-work resting heart rate (HRrest) measured while seated during the period prior to blood sampling are shown in Table 5. An analysis of variance of mean resting HR for those subjects with paired data (pre to post) showed a significant increment throughout the sampling period for both the pre-work HRrest and the post-work HRrest. Regression analysis for all sample dates showed a significant increasing trend in the post- work HRrest (R^2=0.382, t_{30}= 24.9, p≤0.05) but not in the pre work HRrest although a positive slope was observed in these latter data. Further regression analysis of the daily increase in HRrest from pre- to post-work (ΔHR_{rest}) showed a significant and a progressive rise during the planting season (R^2 =0.243, T_{25}= 2.779, p≤0.05).

Table 5. Showing pre- and post-work resting heart rate during seven sample dates. Bottom row shows the group mean resting heart rate for each sample date, and the right column is the individual resting heart rate mean for the season.

Day	1	8	15	24	32	58	75	Mean
Ss I.D. **Pre**								
6	83	81				66		74
7		87						87
8			72	77				75
9								
10	63		55	66	64	66	91	68
11	83		68	60	56	72	86	68
12	63							
13			55	60	68	78		65
14			53	54	48		51	52
15	80	42	52	54	72	66	64	58
16			64	64	64	56	60	62
17	81	66	64	57				62
18			50	48	60	60	48	53
19				66	72			69
20		52	64	60	60	60	60	59
21		58	66					62
Mean	75.5	64.3	60.3	60.5	62.7	65.5	65.7	65.3
Post								
6	80	84						84
7			76		70			73
8		87	82					85
9			72					72
10		64	68	76	76		126	82
11	83	84	88				92	88
12	74		63	83	80			75
13	72	57	65	95				72
14	85		80	95			100	92
15	84	72	68				112	84
16	80	64	68		86		100	80
17		64	72	76				71
18	59	58	72				82	71
19	84	72	90					81
20			72		80		76	76
21	107	86	84					85
Mean	80.9	70.8	74.7	85.0	78.4		98.3	79.0

Resting Blood Pressure

Resting blood pressure (BP_{rest}) data was obtained on 5 sample dates during either the pre- or post-work period, and only on day 75 was BP_{rest} measured during both the pre- and post-work sample time (Table 6). For the paired data on day 75 no significance was observed between pre- and post-work BP_{rest} for both systolic and diastoilic pressure. Comparison of sample date means showed significance only for pre-work diastolic BP (ANOVA, F_{31} = 5.115, $P \leq 0.05$).. Regression analysis of pre-diastolic BP_{rest} was significant ($F_{1,29}$ = 9.196, $P \leq 0.05$) as diastolic BP gradually reduced throughout the sampling period. No other trends were apparent in these data.

Health Questionaire Data

A health questionaire record was completed by each of 13 subjects on a daily basis for either the entire planting period or a portion of it. The average number of health concerns per subject was 1.5. Subject 11 and subject 20 were relatively high complainers with 4.5 and 3.9 complaints/day respectively, and subjects 16 and 19 were low complainers (0.3 and 0.1 complaints/day respectively). The total number of complaints/day for each subject and a ranking of their frequency is shown in Table 7. The most frequently reported complaints were fatigue, joint swelling, back pain, muscle weakness, and nose running.

Table 6. Showing pre- and post-work resting blood pressure during six sample dates. The bottom row shows the group mean resting heart rate for each sample date, and the right column is the individual resting blood pressure mean for the season.

Ss I.D.	Day 1 Pre	Day 27	Day 33	Day 38	Day 58	Day 75	individual me an
6					120 72		120 72
7							
8		120 78					120 78
9							
10		111 78	122 76		110 68	110 70	113 74
11		118 78	120 80		128 68	110 70	119 75
12		112 74					112 74
13		128 80	122 82		128 78		126 80
14		126 82	120 80			134 78	127 81
15		116 80	122 82	138 82	118 72	110 75	121 79
16		136 84	142 80	141 81	132 78	123 60	135 81
17		118 80			128 78	126 88	124 79
18		128 82					128 82
19		124 76	140 90				132 83
20		118 78	128 88		110 70	112 82	117 79
Mean		121 79	127 82	140 82	122 73	118 75	123 79
	Post						
6	134 70						134 70
7							
8	110 60						110 60
9							
10	123 73					124 84	124 79
11	125 56					114 60	120 58
12	118 65						118 65
13	143 110						143 110
14	164 65					142 80	153 73
15	120 64					106 64	113 64
16	150 90					143 80	147 85
17	132 80						132 80
18							
19	138 82						138 82
20							
21	138 85						138 85
mean	133 75					126 74	129 74

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Table 7. Health questionaire data from 13 subjects reported on a daily basis during the planting period. Symptoms are ranked in decreasing order by percent of subjects ever complaining and frequeny of reporting (right columns). The bottom row shows the individual mean number of complaints reported per day.

Symptom/ Ss I.D.	8	10	11	12	13	14	15	16	17	18	19	20	21	%Ss comp	%time c cmpl
fatigue	2	22	33	0	16	3	9	9	13	4	0	40	7	84.6	28.5
joint swellng	0	23	12	25	27	10	1	6	27	0	0	40	2	76.9	36.0
back pain	4	23	11	0	15	0	1	5	0	3	0	40	7	69.2	25.6
muscle weakness	4	1	29	0	27	5	5	1	0	4	0	0	0	61.5	17.4
nose running	0	3	6	0	0	5	2	0	6	3	1	29	0	61.5	12.4
coughing	5	1	27	0	0	0	2	1	0	6	0	12	0	53.8	14.3
irritability	0	15	26	0	1	1	8	0	1	0	0	0	1	53.8	12.7
depression	2	10	22	0	4	0	5	0	0	0	0	1	1	53.8	11.7
skin rash	0	3	7	0	0	0	2	0	2	2	4	2	0	53.8	5.1
muscle cramp	3	2	0	0	5	1	4	0	0	0	0	20	0	46.2	11.0
eye irritation	2	9	13	0	2	0	3	0	0	2	0	0	0	46.2	8.7
abdominal pain	0	4	6	0	12	0	1	0	4	1	0	0	0	46.2	8.2
night sweat	0	5	2	0	1	0	1	0	0	1	0	17	0	46.2	7.6
sore throat	1	0	3	0	0	4	1	0	0	0	0	6	1	46.2	6.1
headache	4	0	7	0	2	0	1	1	0	0	1	0	0	46.2	5.6
nose iritation	0	13	17	0	0	0	15	0	0	1	0	1	0	38.5	14.0
loss of appetite	1	11	6	0	0	7	1	0	0	0	0	0	0	38.5	8.9
nausea	0	4	9	1	0	0	1	0	8	0	0	0	0	38.5	8.5
insomnia	0	4	5	0	2	5	1	0	0	0	0	0	0	38.5	5.9
constipation	0	3	3	0	1	0	1	0	0	0	0	3	0	38.5	3.6
muscle twitch	0	0	3	0	0	1	1	0	0	0	0	3	0	30.8	3.5
dizzyness	0	1	8	0	0	0	1	0	0	0	0	0	0	23.1	5.5
blured vision	0	0	1	0	3	0	1	0	0	0	0	0	0	23.1	2.9
diarrhea	0	0	2	0	0	1	1	0	0	0	0	0	0	23.1	2.3
heart problem	0	0	2	0	0	0	1	0	0	0	0	1	0	23.1	2.2
nose bleed	0	1	0	0	1	0	1	0	0	0	0	0	0	23.1	1.5
diary days	29	75	58	30	54	48	75	76	47	66	66	55	13		
total #complaints	28	158	260	26	119	43	71	23	61	27	6	215	19		
# complaints/day	1.0	2.1	4.5	0.9	2.2	0.9	0.9	0.3	1.3	0.4	0.1	3.9	1.5	mean= 1.5	

Blood Variables

general

Data from each subject's blood variable for each sample day was pooled for both the pre and post work sample to determine a group mean difference (pre-post) in each blood variable. A significant ($p \leq .05$) post-work group mean rise of ESEA occurred and a significant decrease was observed in the blood hematology ($p \leq .05$). Due to the strong diurnal nature of cortisol a pre- to post-work comparison was not made.

For each blood parameter a group mean pre- and post-work value was calculated for each sample day for the subject group. Due to subject attrition and the exclusion of the last 2 sample dates due to their occurrence on the 5th and 6th days of a work shift, the group mean blood data for analysis was limited to 10 subjects (9 male and 1 female) who participated in 6 or more sampling sessions (representing days 1-32 of the planting season). This treatment of the data allowed a 2-way within subject ANOVA comparison to be made.

Elevated serum enzyme activity: (ESEA)

Figure 6 shows the group mean ESEA induced by tree planting. A significant ESEA (CK, LDH, AST) above the group mean pre-season control value, (paired t-test for unequal sample sizes, $p \leq .05$) occurred in both pre and post planting blood samples, (days 1-32), even for " day 0"(camp set up) above a base line control enzyme activity measured in a group of planters previous to the season's start (Figure 5).

CK

Post-work CK peaked 8 days into the season and subsided thereafter to a

substantially lower, but still significantly elevated level above the initial control, pre-season activity. A significant pre to post work elevation of CK was observed only during the first three sample dates. The mean pre-work value showed little change between sample periods and probably reflected the 2 days of relative rest preceding each sample collection, yet each mean sample period value remained elevated above the pre-season control (Fig. 5a).

LDH

Both pre and post LDH activity rose steadily throughout the planting period reaching a significant elevated level in both the pre and post work sample respectively on days 8, and 32 relative to the baseline activity of the enzyme prior to planting (day 0). The only significant pre to post work elevation of LDH occurred on day 8, coincident with the day of the highest CK elevation (Fig. 5b).

In order to test further the rising trend seen in LDH, data for all sample dates were pooled from subjects who had completed eight weeks of prior planting work before day 0 of the current study. This group mean was then compared with the remaining group of planters. The results shown in Figure 6 demonstrate a slight yet non significant decrease in both pre- and post-work serum LDH concentration in the former group..

AST

AST activity showed a similar pre and post work elevation paralleling the pattern of change in LDH up to day 15 (Fig. 5c) declining thereafter similarly to CK through to day 27 before rising transiently again on day 32.
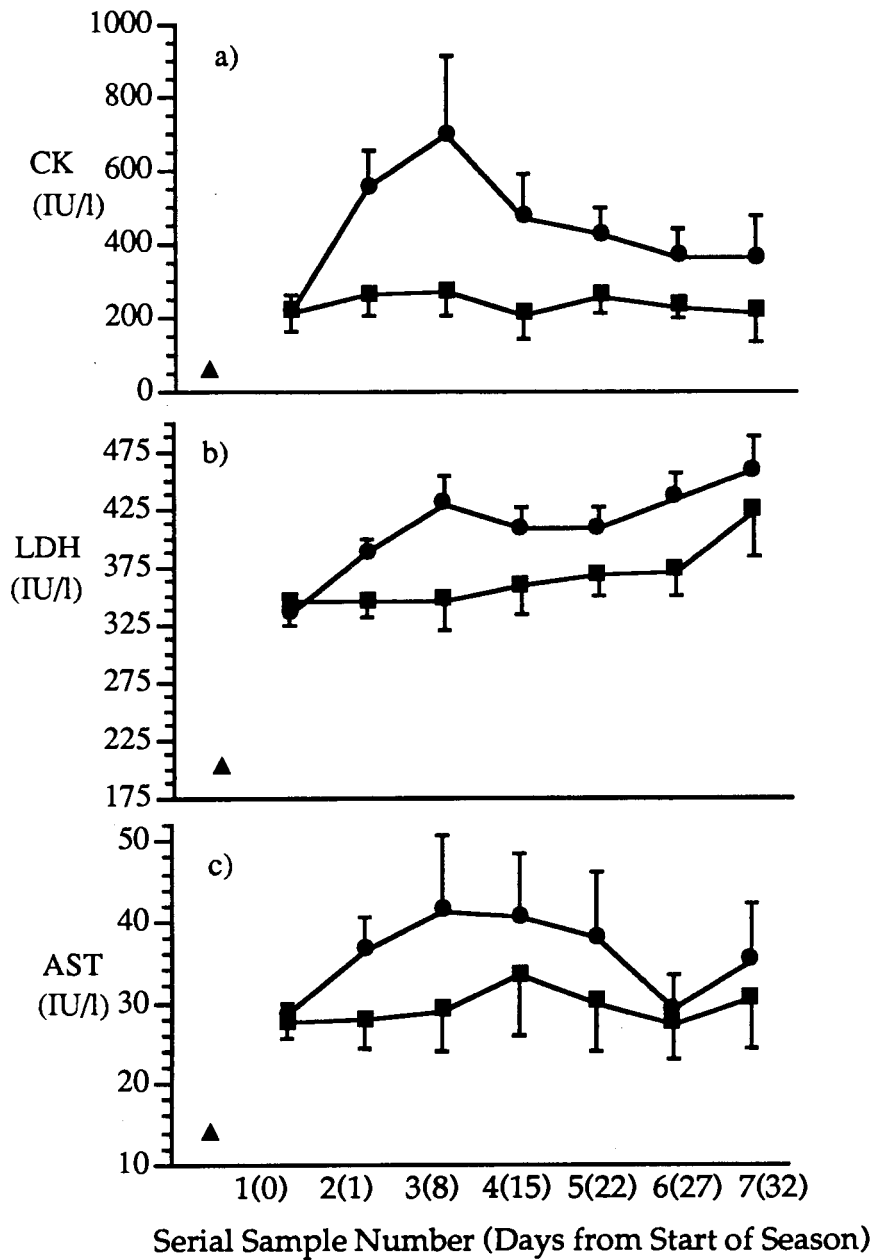
Figure 5. Group mean data (± SE), for CK, LDH, and AST from tree planters on 8 sample dates. Days 1 through 32 are serial measures from 10 Ss throughout a planting season. Day 0 is an in-season control (camp set up) n=8; a pre season control group, (▲), n=9, was obtained from an independent group of planters. Symbols ■ and ● indicate pre-work and post-work sample times respectively.
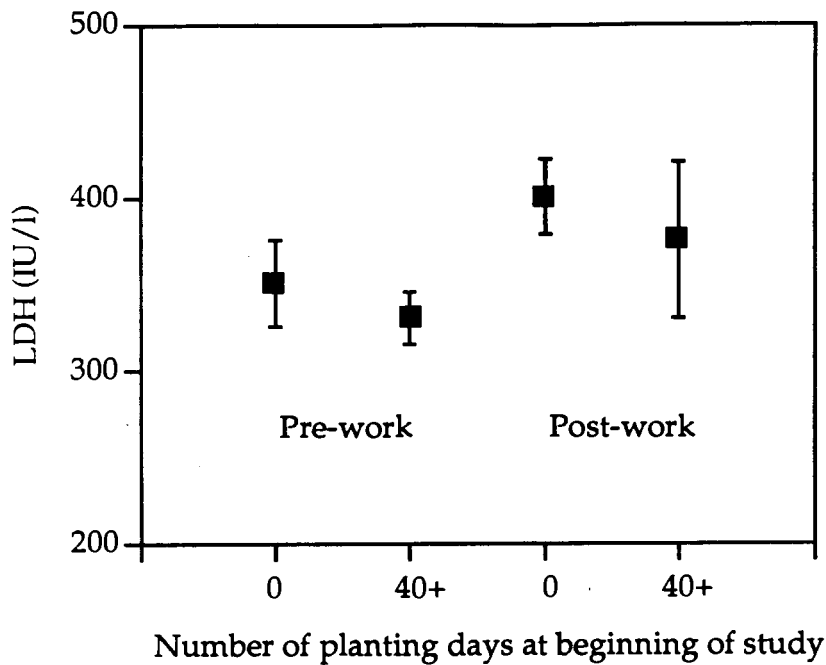
Figure 6.   Pre- and Post-work comparison of group mean serum LDH concentration, for all sample days, of subjects with eight weeks of prior planting (n=4) and those starting at the beginning of their season (n=12).

Blood Hematology

RBC, Hgb, and Hct showed no significant variation throughout the period. However a general decreasing trend in group mean data of these parameters may be observed from the control (day 0) onwards throughout the season (Fig 7). This group mean pattern is typical of several individual profiles.
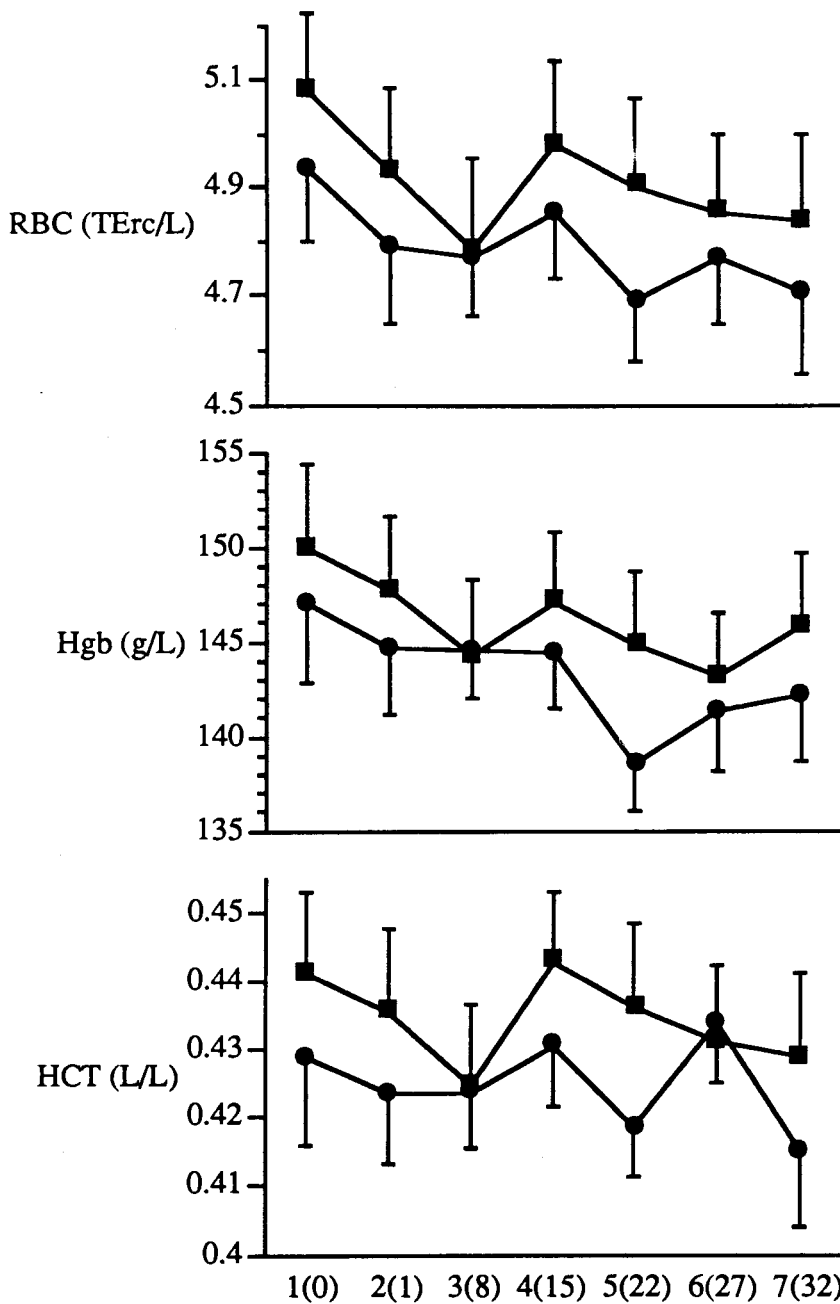
Serial Sample Number (Days From Start of Season)

Figure 7. Blood hematological data, (group means ± std. error), for RBC, Hgb, and Hct. Days 1 through 32 are serial measures from 10 Ss throughout a planting season. Day 0 is an in-season "control" (camp set up) n=8. Symbols ■ and ● indicate pre-work and post-work sample times respectively.

Cortisol

The distinct diurnal rythm for cortisol does not allow a pre- to post-work comparison. In addition, controlling for the time of sampling is an important consideration. For this reason several data for this variable were discarded for the following reasons:

The post-work sample on day 38 was discarded due to its late sampling time during the evening instead of immediately after work. This value was markedly lower compared with other post-work samples. Day 32 was eliminated due to a earlier than normal sample time (4:00 A.M. and 3:00 P.M.) because of a fire shift call (an abnormal camp activity against a forest fire). The pre and post-work values of subject 14 on day 75 was elimated due to his several hours of sleep deprivation. The post-work value of subject 11 on day 8 was discarded due to her slipping and falling in a cold stream just prior to sampling. The measured cortisol concentration of this sample was markedly higher (934 μmol/l) than normal.

Remaining data for cortisol concentration were plotted and tested for statistical variance throughout the sampling period dates and are shown in Figure 8. Pre-work group mean cortisol variance throughout the sampling period was significant (F=2.31, p≤0.05). Post work variance however was not significant (F=1.913, p>0.05). A post hoc paired t-test between pre-work measures foundsignificant differences between the first and last sample dates a (days 1 and 72), between days 8 and 38, and between day 75 and days 1, 8, 15, 22, and 27 (p≤0.05).
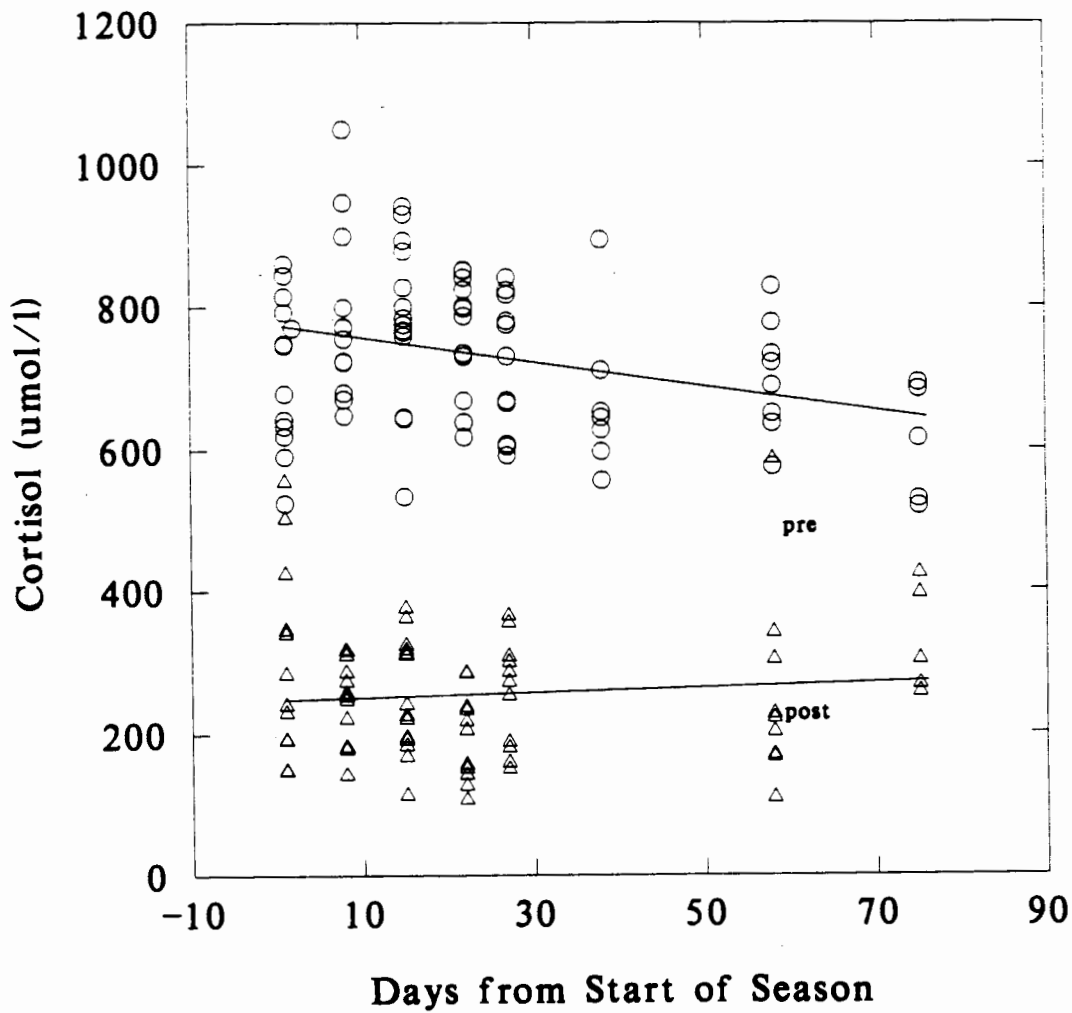
Figure 8. Pre- and Post-work serum cortisol concentration for the subject group (n=16), during a 75 day planting period (o = pre-work, Δ = post-work).

Further analysis compared subjects with eight weeks of prior planting work before day 0 of the current study with the remaining subjects for all sample days combined. The results are shown in Figure 9 and show a slight yet non significantly higher pre- and post-work serum cortisol concentration respectively in those planters with most accrued planting days.
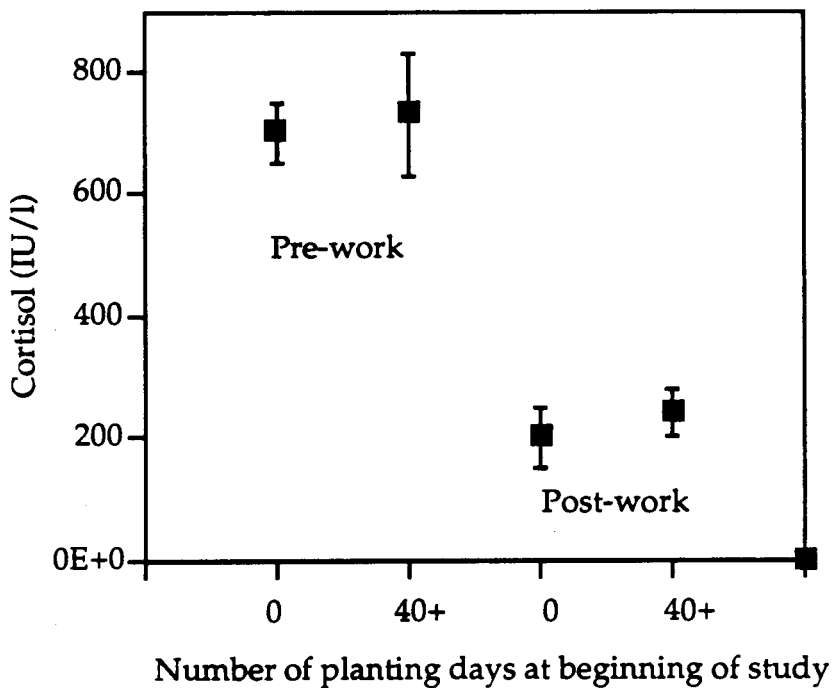
Figure 9. Group comparison of pre- and post-work serum cortisol concentration for subjects with 40 prior planting days at the beginning of the study and for subjects at the start of their seasson (0).

Planting experience

When the results of the fitness test (PWC170) were compared with the number of years planting experience, subjects with more planting experience generally were more fit compared with novice planters ($F_{4,45}$ =3.5, p≤ 0.05). Inexperienced planters of who also comprised the least fit of all subjects tested compared poorly with experienced planters

A tree planting rate (trees/min) was calculated for each planter by dividing the reported number of trees/day planted by the number of productive minutes of work performed/day (total time spent in the field - total rest time). This information was obtained from the questionnaire data as described in appendix B. When planters were grouped by number of years of experience a significant difference in productivity was determined between the novice planter, a planter with between one and three years experience, and one with four or more years experience (p≤0.01, Fig. 10).
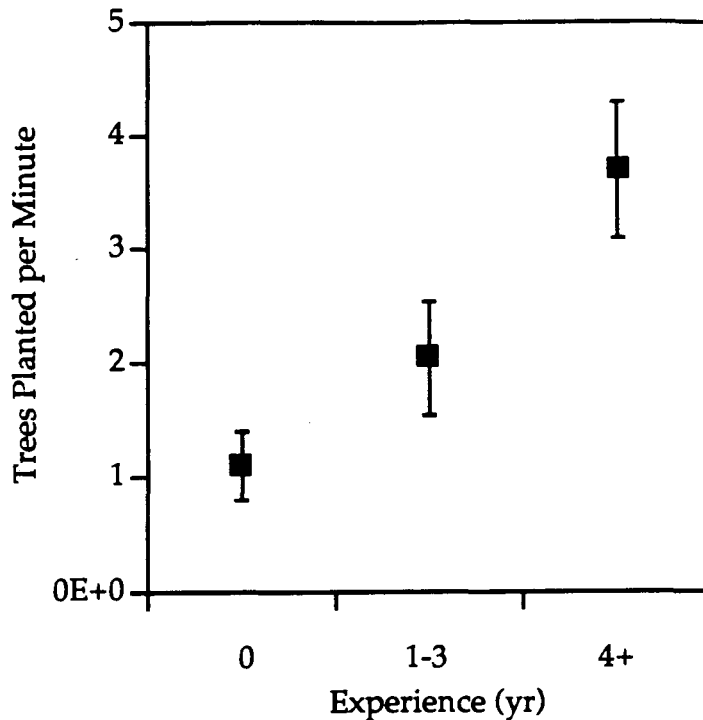
Figure 10. Years planting experience versus planting rate (trees/min).

Summary

These data have shown tree planting to be strenuous activity as evidenced by a long work day and a significantly elevated working heart rate equivalent to 39.2% ΔHRratio (estimated equivalent to 46% $\dot{V}O_2$max.) and a significant daily body fluid loss of 2.8*l*. SEA were significantly elevated throughout the planting period indicating minor trauma to the musculature. Blood hematology parameters gradually decreased (not significant) during the planting period with a pre- to post-work daily decrease which was not significant. Slight increase in pre-work resting HR was seen during the planting period yet post-work resting HR and Resting Blood pressure did not vary significantly. Pre-work group mean serum cortisol concentration variance throughout the sampling period was significant. Post-work variance in cortisol concentration however was not significantly changed throughout the sampling period.

Discussion

Energy Expenditure

The perception of workers in the industry is that silviculture work is strenuous and hazardous and this concern for health and safety may be a major reason for labour instability in the field (Smith 1987; Silviculture Joint Adjustment Committee Report 1988). That tree planting is energetically taxing is evident from the high planter working heart rate maintained throughout an 8 hour work day in this study.

The mean relative energy expenditure of 39.2% of ΔHRratio (estimated equivalent to 46% $\dot{V}O_2$max.) for an 8 hour work day found in this study is comparable to the relative energy expenditure found by other authors in studies of other kinds of freely-paced work. In tree planting studies Giguere *et al.* (1991) reported a group mean value of 121.7 ± 19 b·min^{-1} for the working heart rate in central Canadian tree planters. Smith (1987) has previously reported a group mean HR of 135 b·min^{-1}, equivalent to 60% of the estimated $\dot{V}O_2$max for an average observation period of 132 min. One explanation for this latter higher work rate heart rate compared with the present study may be the higher cardio-respiratory capacity determined for the subject group in the present study. The demonstrated relationship between a planter's PWC170 statistic and their corresponding working HR in figure 4 shows that an increased cardirespiratory capacity is associated with a lower working HR. The PWC170 statistic in Smith's study (1987) was 196 ± 46 watts (range 135-237), (n=4) compared with 245.5 ± 48 (range 143-309) (n=10) in the current study.

Setting a work rate limit for tree planting work.

Many authors have attempted to establish an optimal work rate limit, expressed in terms of a percentage of maximal aerobic capacity of the worker, which would be appropriate to a specific occupational task. Recommendations range from an average of 30% $\dot{V}O_2$max up to 50% $\dot{V}O_2$max for an eight hour day (Astrand and Rhodahl 1986; Saha *et al.* 1979; Evans *et al.* 1980; Grandjean 1983; Oja *et al.* 1982; American Industrial Hygiene Association 1971).

To date a recommendation for a particular maximal work rate during an 8 hour day would have little empirical justification. Grandjean (1983) suggested a limit on the working heart rate for continuous effort set at a level 30 beats above the resting heart rate. Oja *et al.* (1984) has recommended a 40% $\dot{V}O_2$max criterion based on experimental results which indicated that a work rate set at 50% of maximal led to a developing lactacidemia in many people. In a laboratory study, Astrand (1960) found a higher heart rate and $\dot{V}O_2$ during the last hour of pedaling work in each of four subjects exercising at 50% of $\dot{V}O_2$max for a period of 8 hr. Based on these findings the author recommended a 50% $\dot{V}O_2$max workrate not be surpassed during an 8 hour work period. Astrand and Rodahl (1986) recommended a 40% $\dot{V}O_2$max standard, after stressing the fact that a worker should not feel fatigued and be without sufficient vigor to enjoy adequate leisure at the end of a day's work.

Saha (1979) recommended 35% $\dot{V}O_2$max. Kemper *et al.* (1990) proposed a mean energy expenditure of 30% $\dot{V}O_2$max with no more than 60 min/day spent developing energy expenditure above 50% $\dot{V}O_2$max for refuse collectors in Scandinavia. Kemper *et al.* (1990) have suggested a 33% $\dot{V}O_2$max load, reducing the 40% $\dot{V}O_2$max load recomendation by Astrand (1977) due to the high use of arm work in refuse collecting which reduces the $\dot{V}O_2$max by as much as 30%.

In industry, heavy physical labour and manual material handling is positively correlated with developing major health problems (Bager 1981) ultimately leading to sickness and disability in the work force, personal suffering, clearly an unwanted economic burden.

Reducing the work rate of tree planting may, for many individuals reduce their risk of debilitating health or injury problems. The effect such action may have on productivity remains to be investigated.

Workrates from labor intensive occupations

Swedish motor manual loggers, working at their own pace on a piece work basis, averaged a work rate of $49 \pm 7\%$ $\dot{V}O_2max$ during a 5 hour work day at a HR of 123 ± 4 b·min^{-1} (Kukkonen-Harjula and Rauramara 1984). Various modes of postal delivery (simulated) range from 30.6 to 54.3% of $\dot{V}O_2max$, at a HR of 104-136 b·min^{-1} when the postal worker was instructed to deliver mail at his or her own free pace along an estimated 600 meter course (Ilmarinen *et al*. 1984). The highest task level of energy expenditure, (1.7 1/min, 54.3% $\dot{V}O_2max$) was found for climbing stairs or bicycling lasting 7 minutes. It is difficult however to project if such a work rate could be sustained throughout an 8 hour work day. A similar study on postal workers for a longer period of time (hours) showed a workrate equivalent to 40% $\dot{V}O_2max$ (Kalleta, 1980).

Sustained freely-paced work seems to be chosen between 30% and 50% of $\dot{V}O_2max$ depending on the task characteristics and the incentive of a worker. Hughes and Goldman (1970) found that subjects adjusted their walking pace at a constant energy output of 425 kcal/hr $\pm$ 10% to accommodate an imperceptibly varying treadmill speed. This suggests that an individual adjusts their rate of

work in order to maintain a constant work output (work pace) in the presence of a changing task load.

Compromised Rest and Leisure

The pie chart in Figure 2 shown for the duration of a 24 hour day appears to reflect a normal time distribution for an 8 hour industrial work day. However there are various qualitative factors unique to the organization of tree planting work.

The length of the work day (8.33 hours) 20 minutes longer than a normal industrial shift, does not include transportation time (80 minutes/day), and contains 40 minutes less break time. Delays in production due to circumstances out of the tree planter's control (i.e. finished area early, run out of trees and waiting for delivery, flat tires) were reported as breaks in the present study. Tree planters consider working time as only that spent planting under a piece work incentitive. In contrast a delay in salaried work, when production is lost, is still considered work time. A delay in tree planting is often taken as opportunity to eat, rest, drink fluids, or smoke.

The evening leisure time shown in figure 2 is not uniquely devoted to leisure persuits in these remote work camps. A high degree of personal organization is required to live in the bush. Shelter space is limited and personel provisions are minimium. Each evening equipment, and clothing must be prepared for the next day of work. Some examples of this are: changing corks and boot laces, darning clothing, replacing a shovel blade, cleaning clothes, or drying clothes after a wet day. There are also numerous camp chores such as making fires, starting and stopping the electrical generator and the water pump, and in many camps planters must wash the cooking and eating utensiles. Certain days

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allow more free time than others and some individuals organize leisure time better than others. Overall leisure time is 3.5 hours/day at the most, and is frequently disrupted leisure time at best.

Work Efficiency and Piecework Incentive

The total time spent in actual planting, 7.5 hr/day out of 8.5 hr available, corresponded to 88% of the available daily field time and is similar to other findings. Smith (1987) found a planting time relative to total field time of 73%. Banister *et al.* (1990) indicated one of 83%, with an average, additional 5% of each work day (.5 hr) lost to late seedling delivery; workers waiting for more planting area; waiting for transportation; or waiting for supervision. The remainder of the work day (.8 hr) was spent eating, organizing, and resting. Giguere *et al.* (1991) found a proportionate field time of 68.5%-87.7% in 4 eastern Canadian planters. The lower end of this range was explained by an unusually long rest period due to late arrival of seedlings.

One explanation for this hard work schedule may be the piece-work payment incentive.

Estimation of work rates from cycle ergometry

Standardization of the job-task heart rate against a cycle ergometry standard to determine the on-the-job energy expenditure is somewhat imprecise yet useful and widely practiced. Astrand and Rhodahal (1986) do not perceive the need to simulate the exact work task under study when estimating work intensity of the job. Other research has shown that the type of work performed influences the HR/ $\dot{V}o_2$ metabolic relationship (Evans *et al.* 1980,). Mass *et al.* (1989) found that prediction of $\dot{V}o_2$ from HR during static work is not accurate; a difference

between 78% and 186% of the directly determined metabolic cost has been determined depending on the degree of static work involved. A combined static-dynamic task was found to predict HR task $\dot{V}O_2$ accurately from measured HR when the amount of carried weight was small (4, 8 and 10 Kgs.). A larger carried load increased the error in predicting task $\dot{V}O_2$ from HR (12 Kgs overestimating $\dot{V}O_2$ by 38%). Factors known to modify the slope of the linear realationship between heart rate and $\dot{V}O_2$ are size of recruited muscle groups for the task (Sternberg *et al.*), the degree of static work performed, (Kilboom and Persson 1981), steady or non steady state work, ambient temperature, stress and dehydration. An increase in heart rate without a proportional increase in $\dot{V}O_2$ has been reported under conditions of stress, heat, recruitment of small muscle groups such as arm work, cyclic or variable work, static work and dehydration. Neilson and Meryer (1987) show that the $\dot{V}O_2$ estimated from heart rate significantly overestimated the $\dot{V}O_2$ during industrial work. Static muscular activity and the non steady state characteristics of the work generated the highest degree of overestimation.

Tree planting work has components of static work and unsteady state conditions. Another source of error when predicting $\dot{V}O_2$ from the working HR measure in tree planters is the degree of arm work involved in shovel work and planting the seedling. However the predominant component during the planting cycle is dynamic muscular effort. Dehydration is a likely factor affecting heart rate, especially toward the end of the work day and especially during hot and humid conditions noted during the later part of the study period. Thus there is probably some overestimation of the planting workrate in this study when calibration of the workrate was standardized for the HR/workrate relationship from cycle ergometry. While the exact amount of error remains undetermined it is unlikely to be large and, for the purposes of this study the working HR provides a general

evaluation of metabolic requirement of tree planting work. The determined planting heart rate record obtained during field work directly from the planter more accurately reflects the cardiovascular strain incurred by tree planting work rather than the calculation of metabolic cost. The situation of field work is such that measured physiological variables are an integrated response to work place stress (Teiger *et al.* 1982) and are effectively represented by the heart rate response.

Elevate serum enzyme activity

The group mean pattern of ESEA, particularly the acute elevation of CK activity, may be regarded as a significant indicator of minor developing pathology in muscle (Armstrong 1990; Janssen *et al.* 1988; Clarkson and Tremblay 1988) and is consistent with the chronic strenuous physical nature of the job. The pre-work ESEA values for each sample day are consistently higher when compared with the pre-season control group value, (Fig. 5), and this depicts the residual effect of the previous day's activity. Some explanation of the observed ESEA following exercise has been attributed to a calcium activated initial lipolytic digestion of cellular structures (Jackson *et al.* 1986) and a secondary overall inflammatory and phagocytic response (Armstrong 1990) inducing a transient enzyme leak from the muscle cell to the interstitial and vascular space which produces the observed ESEA shown in Figure 5. Muscle weakness, soreness, general tiredness, and even frank pathology may result (Davies and White 1981, Friden *et al.* 1983) especially if one is unconditioned to the activity.

It is noticeable in the present study that silviculture workers, as do athletes in training, gradually made adaptation to the strenuous nature of the work stress (training) as the season progressed since the group mean post work total serum CK activity abated, although it remained considerably elevated above the rested pre-

season control group value (Fig. 5a). The group mean rise in serum CK activity in the present study up to day 8 (Fig. 5a), followed by a gradual decline through to day 32 may therefore reflect some skeletal adaptation of the worker to tree planting. This gradual decline in CK is consistent with studies in the literature demonstrating that repeated trials of an identical exercise stimulus produce a smaller ESEA (Roxin *et al.* 1984; Clarkson and Tremblay 1988; Saunders and Bloor 1975; Buyze *et al.* 1976). However the continued elevation observed in serum LDH activity (Fig. 5b), well above the pre-season control group, suggests some ongoing strain to the skeletal system specifically reflected by the LDH enzyme flux. That there was evidence of adaptation of ESEA in some enzymes leaked to the vascular space is a positive sign of the work-force's overall adaptation response although within the group some workers adapted only slowly.

Hematological Deficiency

The trend for the haematological variables (Fig. 7) to decrease although not significant parallels the so called "sports anaemia" or "pseudo-anaemia" commonly observed in the well trained endurance athlete, many of whom demonstrate a chronic lower haemoglobin and hematocrit than the non athlete (Magnusson *et. al*, 1984). None of the subjects in this study may be classified as anaemic (defined as <140gm/l Hb for men, and <120 gm/l for women).

The acute daily decrease in the post work RBC, Hgb, and Hct concentration respectively is an unexplained finding. These data suggest a plasma volume expansion occurred. However the 3.1% mean decrease measured in pre to post body weight suggests there was also an overall degree of dehydration occurring during each working day. A post-work shift in body fluid, from the extravascular to the vascular compartment is a possible explanation for the observed effect.

Thus osmotic movement of water to the vascular space might occur due to the acutely elevated post work total plasma protein concentration resulting from enzyme leak to the vascular space in the post work blood sample.

With the current lack of knowledge available future research is needed to determine if a developing anemia is a normal adaptation to chronic high performance physical activity or if it is a marker for over work.

Cortisol

Chronic stress results in a rise in serum cortisol concentration indicating hyperactivity of hypothalamic function which, chronically maintained, may ultimately result in exhaustion of secretory cells in the hypothalamus leading to a decreased HPA-axis stimulation. A relatively low concentration of serum cortisol may secondarily affect a person's succeptibility to viral, bacterial agents by its declining activation of the immune inflamatory response (Poteliakhoff 1981). Illness is a common experience and concern among tree planters (PRWA). Chronic fatigue should not be treated as a harmless subjective symptom but should be taken as an indicator of maladaptation to a stressful working environment to which immediate corrective action should be made.

While some decrease in serum cortisol was observed during the 42 planting days in the present study there is not a strong enough pattern due perhaps, to the small sample size to suggest a diminished HPA-axis function caused a developing fatigue. The burnout phenomena described within the planting community is more likely associated with a longer planting period, sometimes up to to 100 planting days. However four subjects with eight weeks prior planting (40 days), at the commencement of the current study showed no difference in their overall serum cortisol concentration compared with the remaining subjects (Fig. 9).

Burnout may be associated with some unique individual characteristic (psychological, fitness level, or a physiological susceptibility), or with a work schedule with minimal rest periods. In the current study rest intervals were unusually long toward the end of the planting period (Fig. 1).

Future studies investigating the 'burnout' or 'staleness' syndrome in silviculture workers would benefit by selecting subjects based on a clinical symptomology characteristic of the overtraining syndrome (Ryan *et al* 1983; Kuipers and Keizer 1988). Matched-control unaffected subjects could be chosen from planters working in the same camp. Such a methodology would not be limited to a particular work camp or time of year, and would not have the problem of subject attrition, and unpredictable work-rest patterns. Corresponding biochemical and physiological data could be compared between the two groups and differences then attributed to accompanying clinical symptomology.

Future Reaserch and Recomendations

The overall management of silviculture activity in the field needs further ergonomic analysis to assess the impact of such changes as discussed above. Further ergonomic study of work-schedule design, equipment design and alleviation of alien environmental conditions to maximize the well-being and efficiency of workers is also needed. Collection of physiological data is especially helpful in determining optimal work rate, minimizing unfavorable working postures, determining efficient movements and avoiding unnecessary work. To date such measures have been only sparsely collected under actual field conditions. The incorporation of effective preventive practice in the work task is difficult due to the multiple health hazards surrounding the worker. This makes an exact hierarchcical ordering of risk factors difficult to establish and difficult to

combat precisely. Based on the data collected and from observation of tree planting work made during the present study the following recommendations are made:

1) *Reduced work-rate.* In tree planting work special attention must be paid to the daily physical load in the work situation. Ensuring the workrate is sufficiently low is an essential work principle in order to maintain the health and productivity of the worker and enable successful completion of contracted work by the industry.

2) *Reconsideration of the piece-work payment system.* The added metabolic 'cost' to the worker attempting to increase production output, which is encouraged by the piece-work payment system, may well be beyond a worker's 'comfortable capacity' to sustain on a daily basis without compromising an individual's well-being in the field. A guaranteed minimum wage standard with the flexibility to introduce a "production bonus" may help to reduce worker stress while maintaining a production incentive.

3) *Better organization of the work cycle.* The inflexible optimal climatic period for establishing seedling plantations, coupled with the high cost of maintaining a remote work-camp, and time spent living away from home, dictates a high work rate must be maintained in each planting detail with minimal rest days between work shifts in an effort to maximize production. However the difference between a 5x1, (5 days work-1 day rest) and a 4x1 work cycle amounts to only 1 more working day per month. The corresponding difference (presently unstudied) in productivity may not differ significantly in terms of days lost to planting but on the other hand may enhance productivity from the improved

frequency of rest interval for the worker. Research is still needed to determine the optimal intensity for sustainable work, and the optimal organization of the work-rest period (i.e. 5-1, 5-2, 4-1, work-rest shift schedule).

4) Improved hand tools. The highly repetitive nature of Silvicultural work creates susceptibility to various over-use injuries in a worker. Repetitive manual exertions involving the hand cause cumulative trauma to the wrist of many workers (Armstrong 1982; Wieslander *et al.* 1989; Hymovich and Lindholm 1966). Certainly much debilitating musculo-skeletal injury (sore backs, shoulders, knees and feet) result from current work practice. Further research is needed to ascertain ergonomic requirements of tree planting hand tools. Tree planting work patterns and techniques must also change to minimize the above debilitating effects. The recent introduction of motorized brushing tools and other new equipment however emphasises the human engineering problems attendant upon using new equipment which would have benefited from ergonomic study during its development prior to rather than after introduction into field operation.

5) Environmental factors such as heat, cold, rain, sun exposure, and flies affect worker comfort, health and productivity. More emphasis is required in assuring the thermal comfort of the planter at work with concomitant protection of the skin. A worker should also be provided with adequate mobile shelter on the work-site itself providing protection from sun, rain, cold, and biting insects. An abundant supply of drinking water should be supplied to the planter at such shelter. Given the daily loss of body fluid observed in the current study, efforts should be made to provide a cool and electrolytically balanced flavoured drink to encourage consumption.

6) *Improved camp conditions.* Camp standards should be made as comfortable as possible ensuring adequate environmental protection, hygiene and nutrition. Camp chores (such as dish washing, or maintaining and operating equipment) should be eliminated from the evening routine of a tree planter to help ensure adequate leisure.

7) *Development of a year round work force.* Coupled with the diminishing supply of old growth forest in British Columbia and the huge backlog of 70 million acres of already harvested forest land across the country an obvious goal is to develop an intensified reforestation policy and enhanced silvicultural practice for ensuring an abundant timber supply. In the past ten years a great deal of knowledge has been gained concerning the forest eco-system and reforestation practice (Lavender *et al.* 1990). Provision in now needed for a skilled and year round forestry crew. A recent Federal and provincial reforestation agreement (FRDA 1985-1990) has identified the need for immediate further regeneration surveys (250,000 hectares), brushing work (36,000 hectares), and tree spacing and fertilization (66,700 hectares), (BCMOF 1986). Establishment of a trained, full time silviculture work force would ensure a successful reestablishment of new forests.

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Appendix A

History Questionnaire

NAME: _____ SEX: _____

AGE: _____ HEIGHT: _____ WEIGHT: _____

PHONE NUMBER: _____

ADDRESS: _____

CITY: _____ PROVINCE: _____

POSTAL CODE: _____

S.I.N. _____

HOW MANY YEARS HAVE YOU BEEN TREEPLANTING? _____

WHAT JOBS HAVE YOU HELD OVER THE PAST FOUR MONTHS? _____

_____

HAVE ANY OF THESE JOBS INVOLVED CONTACT WITH PESTICIDES? _____

_____

DO YOU HAVE ANY CURRENT OR CHRONIC MEDICAL CONDITIONS? _____

_____

ARE YOU ON ANY MEDICATION? _____

IF YOU SMOKE, HOW MANY CIGARETTES/DAY? _____

IF YOU DRINK, HOW MANY DRINKS/DAY? _____
                    OR DRINKS /WEEK? _____

IF YOU USE 'ILLICIT' DRUGS, WHAT? _____
          HOW OFTEN? _____

ARE YOU VEGETARIAN OR ON A RESTRICTED DIET OR USE DIET SUPPLEMENTS? ____

IF SO, PLEASE DESCRIBE: _____

Appendix B
Work Questionnaire

NAME:						
DATES:						
NUMBER OF TREES PLANTED						
SEEDLING LOT NUMBER						
NUMBER OF TREES PLANTED						
SEEDLING LOT NUMBER						
TIME TO SLEEP LAST NIGHT						
TIME AWAKE THIS MORNING						
TIME OF FIRST PLANTING RUN						
TIME OF LAST PLANTING RUN						
TIME SHOWERED/BATHED						
TIME CHANGED CLOTHES						
NUMBER OF BREAKS						
TOTAL BREAK TIME TODAY						
BUG REPELLANT WORN						
SUNTAN LOTION WORN						
CLOTHING WORN:**						
PANTS						
SHIRT						
JACKET/SWEATER						
HAT						
SCARF						
RAINGEAR						
GLOVES						
PLEASE DESCRIBE GLOVE TYPE:						

**PLEASE USE THE FOLLOWING CODES FOR CLOTHING WORN DURING TREEPLANTING:

W= WORN, NEWLY WASHED   X=WORN, NOT WASHED SINCE LAST WORN FOR PLANTING

L= LONG SLEEVED/LEGGED   S=SHORT SLEEVED/LEGGED

C=COTTON   P=POLYESTER   O=OTHER MATERIAL

EXAMPLE: PANTS   W/L/C= NEWLY WASHED, LONG COTTON PANTS

PLEASE LIST ANY OTHER TREE HANDLING JOBS THAT YOU WERE INVOLVED IN ,
THE APPROXIMATE AMOUNT OF TIME THAT THIS INVOLVED, AND THE DAYS INVOLVED :
FOR EXAMPLE: LOADING SEEDLINGS INTO TRUCK, 1.5 HOURS ON JUNE 4, 5 AND 6.

Appendix C
Health Questionnaire

NAME:							
WEEK OF:							

HAVE YOU EXPERIENCED ANY OF THE FOLLOWING TODAY? PLEASE INDICATE WITH AN X	DATE						
ABDOMINAL PAIN							
BACK PAIN							
BLURRED VISION							
CONSTIPATION							
COUGHING							
DEPRESSION							
DIARRHEA							
DIZZINESS							
EYE IRRITATION							
FATIGUE							
HEADACHE							
INSOMNIA							
IRRITABILITY							
JOINT SWELLING OR PAIN							
LOSS OF APPETITE							
MUSCLE CRAMPING							
MUSCLE TWITCHING							
MUSCLE WEAKNESS							
NAUSEA							
NIGHT SWEATING							
NOSE BLEED							
NOSE IRRITATION							
NOSE RUNNING							
PALPITATIONS/ALTERED HEART RHYTHM							
SKIN IRRITATION OR RASH							
SORE THROAT							

ANY ADDITIONAL COMMENTS OR SYMPTOMS TO REPORT?
(FOR EXAMPLE: IF YOU CHECKED "SKIN IRRITATION" ABOVE, WHAT AREA OF YOUR BODY?)