An Ergonomic Assessment of Manual Planting *Pinus Radiata* Seedlings

Mark. J.M. Sullman and J. Byers
Liro Limited, Rotorua, New Zealand

ABSTRACT

This report summarises findings of an ergonomic evaluation of manual planting under three different site conditions. Heart rate data were collected and analysed using several heart rate indices. The three sites did not differ greatly, producing mean working heart rates that ranged from 132.7 bt.min^{-1} (± 16.2) to 134.9 bt.min^{-1} (± 13.8). Results indicate that manually planting Pinus radiata seedlings on all three sites can be classified as "hard continuous work" or "very heavy work". Planters maintained similar mean working heart rates for all three sites by decreasing productivity as planting conditions became more difficult. Body part discomfort was only experienced when planting on pasture, where slight to severe discomfort was reported 48% of the time. Hazard occurrence was low for all three site conditions.

Keywords: *Planting, workload, forestry, ergonomics, heart rate.*

INTRODUCTION

The majority of New Zealand's 1.3 million hectares of production forests are planted manually. Manual planting is an extremely important task, as the quality of the planters' work will affect the growth of the tree over the next 20 to 30 years and the trees eventual economic return. Accordingly, we would expect that planters would have been an intensively studied group. This, however, has not been the case.

An earlier pilot study investigating the physiological workloads of New Zealand planters [18] found that planting flat, ripped and mounded cutover imposed the highest workload, resulting in a mean working heart rate (HR_w) of 153.1 beats per minute (bt. min^{-1}). Contour planting induced a mean HR_w of 129.6 bt. min^{-1} and uphill planting 144.1 bt. min^{-1}. According to the classification of workload [4], the findings of the pilot study [18], placed contour and uphill planting in the "Very heavy work" category, while planting on flat, ripped and mounded cutover was classified as "Extremely heavy".

The authors are Faculty members at Massey University.

However, the pilot study also found that the productivity differed significantly between the three conditions [18]. Planting productivity on the flat, ripped and mounded site was almost 40% higher than on the other two sites. Thus, it would appear that the increase in physical workload was mainly due to an increase in productivity. This was supported by research conducted in Chile [2], which found that when planters were able to plant at a faster rate, they produced more and hence had a higher physical workload.

A Norwegian study, comparing planting on ordinary terrain and steep terrain, found that the physical workload was nearly the same under both conditions [20]. This research also found that the work output was nearly doubled when the work was performed on ordinary terrain. Therefore, in order to cope with the increased workload imposed on the planter by the steep terrain, the planter reduced his workpace. This phenomena has been termed constant strain behaviour [25, 17].

A Canadian study [19] investigating cardio-vascular and muscular strain among seedling planters, found a group mean heart rate of 116.5 bt. min^{-1}. This placed planting in the "Heavy work" category.

This paper describes the first comprehensive ergonomic assessment of manual planting to be carried out in New Zealand.

METHOD

Subjects

Participation of subjects in the project was voluntary, with each subject being provided with adequate and appropriate information about what their participation involved. Each subject had the right to decline to participate in the project, or withdraw from participation at anytime, without penalty of any kind and without providing reasons.

The study group consisted of six male subjects, with an average age of 23 (range 19-27). All subjects were well conditioned to the job, having on average 1 years experience (range 2 months to 4 years). The subjects normal working day consisted of working from 0700 hrs to 1600, with one rest break 1100 hrs until 1200 hrs. All subjects were paid on a contract piece rate basis. Therefore, payment depended on the number of seedlings each individual planted each day.

Table 1 shows the number of planters measured and the sites on which they were measured. Each planter was observed for one complete working day on each site they worked at.

Table 1. Planters and conditions.

Site Condition	Planter 1	Planter 2	Planter 3	Planter 4	Planter 5	Planter 6
Pasture	yes	yes	yes	yes	yes	no
Spot-mounded	yes	no	yes	yes	yes	yes
Untreated Cutover	no	no	no	no	yes	yes

Physiological Workload

Each subject's heart rate was recorded at 1 minute intervals using a PolarElectro 3000 portable heart rate monitor. Heart rate was recorded for the entire working day, including during the rest break.

Logistical difficulties prevented the measurement of true resting heart rates. Therefore, as soon as the crew vehicle completed the 40 - 90 minute journey to the planting site, the subjects were taken aside and the heart rate monitor was fitted to their chest. The subjects were then asked to sit down for 10 minutes. At the end of this period, the subject's heart rate was recorded as their pre-work resting heart rate. Although this is not the prescribed method for determining a subject's resting heart rate, the payment system used by this crew imposed severe time restrictions on the amount of time the subjects were willing to remain immobile. The use of pre-work resting heart rates has been found to be an acceptable compromise between scientific and production requirements [8, 22].

The heart rate and work task were merged using a 586 personal computer and Microsoft Excel. Analysis was undertaken using Statistics, resulting in the calculation of mean heart rates for each element of the work task. Mean working heart rates (HR_w) contained the sum of the entire working day's heart rate recordings, including those taken during the one hour rest break. Mean working heart rates were converted into three relative measures of strain, the percentage of heart rate range, ratio of heart rate work to heart rate sleep and the 50% level of heart rate reserve.

Planting Techniques

The planting technique varied between the three sites. The pasture and the untreated cutover sites required the three horizontal spade cut method, while the spot mounded cutover required a one spade cut method. The three spade cut method involved making two cuts approximately one spade length apart and then one in the middle. Within the middle cut, the spade was pushed forwards and then pulled backwards to make a bigger hole for the seedling to be planted in. The seedling was then placed roots first into the hole. The soil around the seedling was firmed slightly with the foot and the seedling was pulled up to correctly orient the roots. The soil around the seedling was then firmed in properly with the foot.

The spot mounded area required the planter to firstly firm the mound with their foot, then the spade was placed into the mound to create a hole for the seedling. The soil around the seedling was then firmed slightly, again with the foot and the seedling was pulled up to correctly orient the roots. The soil around the seedling was then firmed in properly with the foot.

Study Location

The study was undertaken at three sites within the central North Island of New Zealand. The pasture component was undertaken on a recently purchased farm block near Te Harotau. The spot mounded and untreated cutover sites were located within Kaingaroa Forest. Kaingaroa is New Zealand's largest plantation forest and covers an area of over 149,000 ha.

Productivity

The activities involved in planting were separated into eight different tasks, and recorded on a Husky Hunter field computer.

The eight work elements were:

Walk in: Walk from the rest area to the area where work began.

Walk out: Walk from the area of work to the rest area.

Plant: Prepare the ground with the spade, planting the seedling, firming in the seedling and walking between seedlings.

Get box: Get a new box of seedlings, change box and return with the box.

Repairs & Maintenance: Repairing or maintaining the spade or other equipment necessary for planting.

Operational delay: Delays caused by work-related concerns.

Personal delay: Delays caused by the workers personal requirements, such as drinking and toilet breaks.

Researcher delay: Delays caused by the researcher, or the researchers equipment.

The time spent undertaking each activity was recorded using the continuous time study programme Siwork 3 [16]. Task-dependant factors such as the number of seedlings planted, and the weight of planting boxes were also collected by the researchers. Box weight was measured using electronic scales.

Hazards

Potentially hazardous situations were defined prior to data collection by a team consisting of experienced planters, ergonomics researchers, and planting researchers. The subjects were closely followed (within 5 metres) by the authors throughout the work day and hazards were noted, using the Siwork 3 programme, as they occurred. Both researchers were experienced in undertaking this type of research.

Body Part Discomfort

Body part discomfort was measured hourly using the modified Nordic method [6]. The planters were shown the body part diagram and asked to indicate where (if at all) they felt discomfort as a result of work. They were then asked to rate how severe the discomfort was on a five point scale, with 1 being "none" and 5 being "unbearable".

Environmental Conditions

Measurement of wet and dry bulb temperatures were taken at 15 minute intervals during the day, using a whirling hygrometer. Measurement was undertaken as close as possible to the area where the subjects were working. The thermal index used was the Oxford Index (WD), where $WD = 0.85t_{wb} + 0.15t_{db}$. ($t_{wd}$ = aspirated wet bulb temperature and t_{db} = dry bulb temperature [15]. An inclinometer was used to measure the ground slope along the direction of planting. Soil shear strength was measured, in megapascals (MPa), using a shear vane.

RESULTS

Physical Workload

The heart rate results are summarised in Table 2. The average work heart rate for pasture was 134.8 bt. min^{-1} (± 14.7), spot mounded was 132.7 bt. min^{-1} (± 16.2), and the untreated cutover was 134.9 bt. min^{-1} (± 13.8). ANOVA revealed there was a significant difference ($P < 0.01$) between the mean working heart rates. A pairwise comparison of the means indicated that mounded was significantly different ($P < 0.05$) from both pasture and cutover. Pasture and cutover were not significantly different. The prework resting heart rates ranged from 55 to 65 bt. min^{-1}. The average relative heart rate at work was 53.0% (± 3.7) for pasture, 51.0% (± 7.8) for mounded and 55.0% (± 5.5) for cutover. The average ratio of HR_w to HR_r was 2.2 (± 0.2) for pasture, 2.1 (± 0.2) for mounded and 2.2 (± 0.1) for cutover. The average ratio of HR_w to 50% level was 1.03 (± 0.04) for pasture, 1.01 (± 0.08) for mounded and 1.06 (± 0.06) for cutover.

The heart rate trace for Subject 1, planting on the pasture, is shown in Figure 1. The trace shows the subjects heart rate from the start of the working day until its completion, including a 40 minute lunch break. The trace is reasonably representative of the five remaining subjects and three planting conditions.

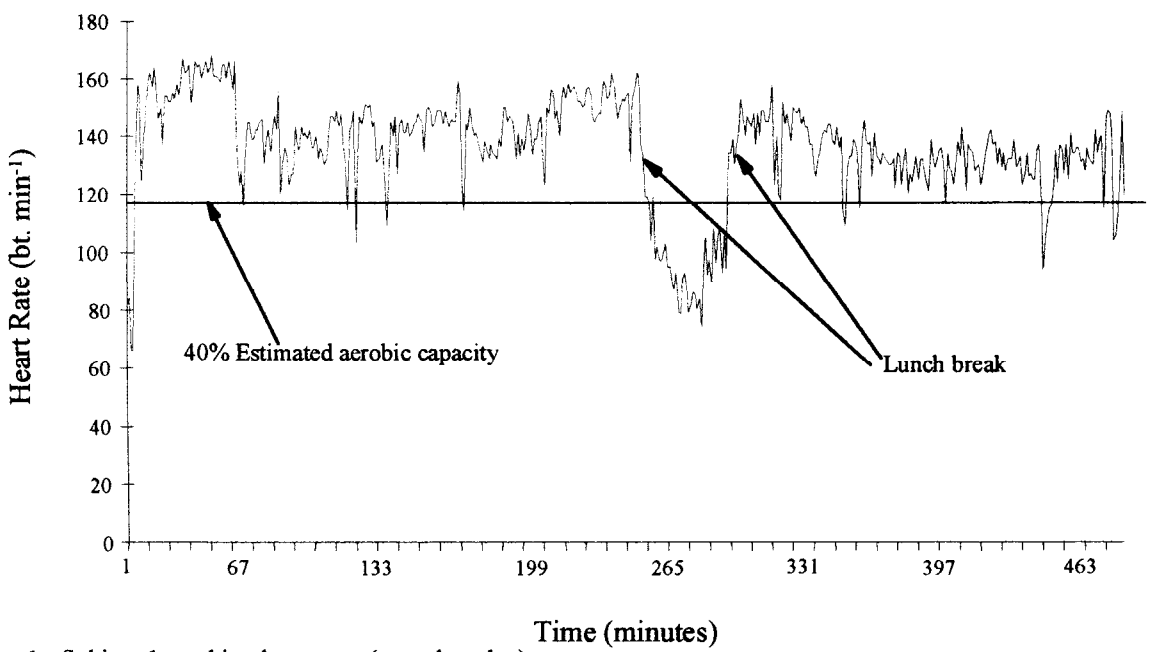

Figure 1. Subject 1 working heart rate (complete day).

Table 2. Mean heart rate indices/subject.

Site	Subject	Age	n	HR_w (+ SD)	HR_r	%HRR	Ratio	50% Level	HR_w 50% Level
Pasture	1	20	496	133 (+ 24.5)	65	50.4	2.05	133	1.00
	2	27	484	128 (+ 19.0)	55	52.9	2.33	124	1.03
	3	21	509	140 (+ 12.6)	60	57.6	2.33	130	1.08
	4	19	420	138 (+ 15.4)	60	55.3	2.29	131	1.05
	5	21	432	128 (+ 15.9)	65	47.0	1.97	132	0.97
	Mean	22	458	134.8	61	53	2.2	130	1.03
		(+2.8)	(+42.8)	(+14.7)	(+3.7)	(+3.7)	(+0.2)	(+3.2)	(+0.04)
Mounded	1	20	240#	127 (±13.0)	65	45.9	1.95	133	0.95
	3	21	232Ψ	136 (± 18.8)	60	54.7	2.27	130	1.05
	4	19	207Ψ	133 (± 9.4)	60	51.8	2.21	131	1.02
	5	21	254Ω	120 (± 11.2)	65	41.0	1.85	132	0.91
	6	25	243Ω	147 (± 12.1)	62	63.9	2.37	129	1.14
	Mean	21	235	132.7	62	51	2.1	131	1.01
		(±2.0)	(±15.8)	(±16.2)	(±2.2)	(±7.8)	(±0.2)	(±1.4)	(±0.08)
Cutover	5	21	240Ω	132 (± 14.4)	65	50.0	2.03	132	1.00
	6	25	79Ω#	143 (± 6.9)	62	60.9	2.31	129	1.11
	Mean	23	160	134.9	64	55	2.2	131	1.06
		(±2.0)	(±81)	(±13.8)	(±1.5)	(±5.5)	(±0.1)	(±1.5)	(±0.06)

Half a days data lost due to equipment failure
Ψ Worked half day due to heavy rain and strong winds
Ω Spent half a day planting on mounded and half a day planting on cutover

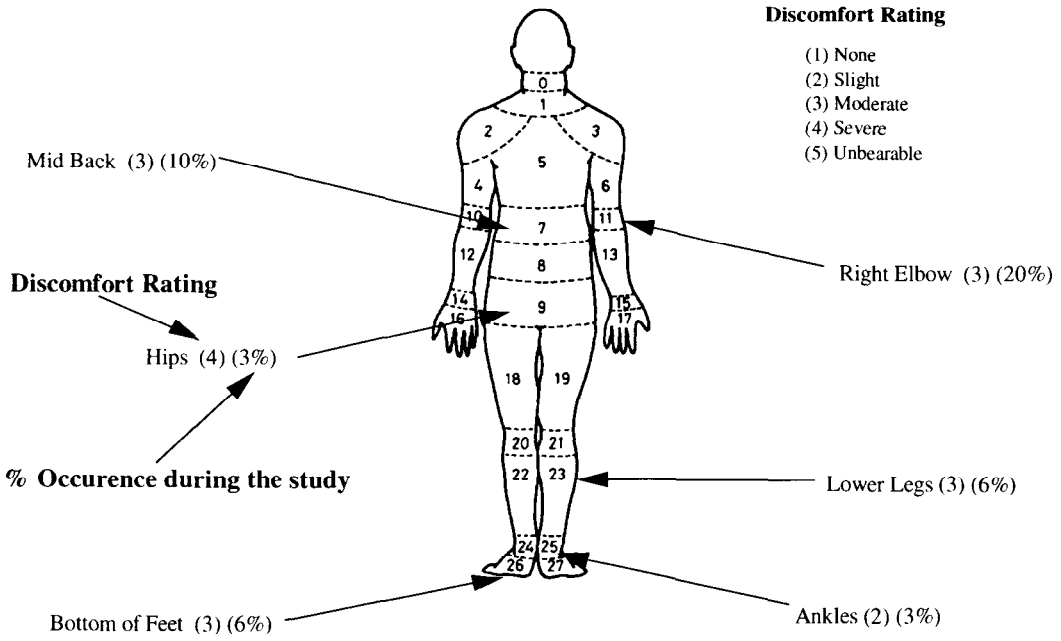

Figure 2. Body part discomfort on the pasture (all subjects combined).

Hazards

The number of hazards per 100 seedlings planted and per hour are shown in Table 3. On the pasture, the number of hazards per 100 seedlings planted was 0.71, meaning that on average one hazard was recorded every 141 seedlings planted. On the mounded site the researchers recorded 0.29 hazards per 100, meaning that on average the researchers noted one hazard per 345 seedlings planted. On the cutover site 0.12 hazards were recorded per 100 seedlings, meaning that on average one hazard was recorded every 834 seedlings planted. The hourly hazard rate was 1.09/hr on the pasture, 0.56/hr on the mounded site and 0.25/hour on the untreated cutover. There were only three types of hazards recorded during the study. Slips accounted for 76% of all hazards, with hitting a solid object (with the spade) or hitting the boot with the spade accounting for the remainder.

Table 3. Hazards by site.

Site	Hazards per 100 Seedlings	Hazards per Hour
Pasture	0.71	1.09
Spot Mounded	0.29	0.56
Untreated Cutover	0.12	0.25

Work Activity

The subjects' working day was broken down into primary activities. The average time spent undertaking each activity, together with the average heart rate for that activity, are shown in Tables 4-6. On the cutover the majority of the time was spent planting (74%), followed by getting a box and walking in (Table 4). There was no time for lunch breaks on the cutover due to the fact that the planters worked the first half of the day on the mounded site, had their lunch break and then travelled to the cutover site, where they worked for the rest of the day. Table 5 shows that on the mounded site, the majority of the time (72%) was spent planting, followed by getting boxes and lunch breaks. Table 6 shows that on the pasture, the majority of the time (72%) was spent planting. The lunch break was the second largest percentage of time, followed by getting boxes.

Productivity

The number of seedlings planted per hour was significantly different for the three sites ($P < 0.05$). A pairwise comparison indicated that pasture was significantly lower than mounded and cutover, but mounded and cutover were not significantly different (Table 7). In terms of box weight, a pairwise comparison indicated that pasture and cutover were statistically different ($P < 0.05$), but neither of the other two comparisons were significantly different. On the pasture the number of seedlings per box was significantly different ($P < 0.01$) from both mounded and cutover, but mounded and cutover were not significantly different. The planting methods differed between sites, with the pasture and cutover sites requiring three spade cuts and the mounded only one.

Table 4. Work activity, average heart rate and task duration -- Cutover.

	n	Average HR + SD	% Time
Plant	237	139.4 + 10.8	74
Get Box	37	125.9 + 12.0	12
Walk in	20	111.5 + 11.5	6
Walk out	7	126.5 + 7.1	2
Personal delay	16	119.3 + 8.6	5
Researcher delay	2	115.5 + 0.7	1

n = number of observations

Table 5. Work activity, average heart rate and task duration --Mounded.

	n	Average HR ± SD	% Time
Plant	851	137.2 + 14.1	72
Get Box	126	124.0 + 16.3	11
Walk in	15	119.5 + 12.4	1
Walk out	16	113.1 + 14.9	1
Operational delay	38	111.6 + 10.5	3
Personal delay	53	114.0 + 8.8	5
Researcher delay	8	122.7 + 5.1	0.5
Lunch break	69	98.4 + 7.1	6.5

n = number of observations

Table 6. Work activity, average heart rate and task duration -- Pasture.

	n	Average HR ± SD	% Time
Plant	1919	138.8 + 11.7	72
Get Box	151	126.4 + 17.2	6
Walk in	27	130.4 + 13.6	1
Walk out	62	131.9 + 19.9	2
Operational delay	45	105.5 + 16.4	1.5
Personal delay	145	112.1 + 9.0	6
Researcher delay	15	121.2 + 7.5	0.5
Lunch break	300	100.4 + 11.0	11

n = number of observations

Table 7. Productivity.

Site	Seedlings per Hour	Weight (Kg)	No. Per Box	No. spade cuts
Pasture	154.0 (+ 42.4)	6.9 (+ 1.9)	147.9 (+ 10.3)	3
Spot Mounded	193.7 (+ 118.2)	6.4 (+ 0.9)	95.2 (+ 7.0)	1
Untreated Cutover	202.1 (+ 78.8)	5.4 (+ 0.4)	95.2 (+ 4.2)	3

Table 8. Environmental conditions.

Site	Slope	Soil Strength (Mpa)	Oxford index
Pasture	22.8 (+ 13.0)	1.53 (+ 0.45)	8.1 (+ 1.2)
Spot Mounded	1.6 (+ 1.4)	0.29 (+ 0.04)	9.6 (+ 2.3)
Untreated Cutover	7.9 (+ 4.8)	0.65 (+ 0.18)	10.8 (+ 0.5)

Environmental Conditions

A pairwise comparison indicated that the slope on the pasture was significantly different to both mounded and cutover ($P < 0.01$), but mounded and cutover were not significantly different (Table 8). In terms of soil strength, all three means were significantly different ($P < 0.01$), with pasture clearly the strongest soil, followed by cutover. The average Oxford index ranged from 8.1°C (+ 1.2) to 10.8°C (± 0.5). A pairwise comparison indicated that pasture was significantly lower than mounded and cutover ($P < 0.01$), although mounded and cutover were not significantly different.

DISCUSSION

Since oxygen uptake during work could not be recorded, metabolic rates at work and energy expenditure could not be estimated. Although measuring oxygen uptake at work would have been preferable, the use of heart rate indices to measure the cost of work has been well established [8, 14, 22, 23]. In fact, relative heart rate at work has been shown to be "an analogous [to VO_2] heart rate index of the cost of work" [14]. Therefore, several heart rate indices were used to estimate the degree of strain experienced while planting on the three sites. These indices could then be compared to those recorded by other studies to obtain some understanding of the severity of the task on the three sites. The indices used were the relative heart rate at work [8, 21], ratio of working heart rate to resting heart rate [8, 22] and the 50% level [8, 12, 22].

The mean working heart rates for the three sites ranged from 132.7 bt.min^{-1} (± 16.2) to 134.9 bt.min^{-1} (± 13.9). The mean heart rates calculated in the current study place manual planting in the "Very heavy work" category (Table 9).

Table 9. Classification of workload [4].

Light work	up to 90 bt. min^{-1}
Moderate work	90-110 bt. min^{-1}
Heavy work	110-130 bt. min^{-1}
Very heavy work	130-150 bt. min^{-1}
Extremely heavy work	150-170 bt. min^{-1}

Compared with other occupations within the New Zealand forest industry, the mean working heart rates recorded here were higher than breakingout 106 ± 6.9 bt.min^{-1} [9], motor-manual tree felling 107 ± 5.5 bt.min^{-1} [11], first lift pruning of Douglas fir 112 ± 10.4 bt.min^{-1} [8], second lift pruning of Douglas fir 126 ± 8.4 bt.min^{-1} [7], manual contour planting 129 bt.min^{-1} [18], but was not as high as uphill planting 144 bt.min^{-1} and planting on a flat ripped and mounded site 153 bt.min^{-1} [18].

The reasons for the recorded mean working heart rates being lower than those recorded by the pilot research [18] were firstly that the individual in the pilot study was the contractor (owner of the planting crew) who wanted to encourage his men to work fast and impress upon the forest company how difficult planting was. Secondly, in the pilot study the crew went home after they had planted the required number of seedlings. This meant the faster the planters worked, the earlier they would get home. This is in contrast to the present study where the planters would finish work after a set time period.

In the pilot study the planter was monitored for 8 hours contour planting, 6.5 hours planting on the ripped and mounded site and 3 hours while planting uphill. Therefore, classifying uphill planting as "very heavy work' may be a mis-classification, as the categories were designed based upon an eight hour day. The ripped and mounded site was close to 8 hours and contour planting was 8 hours, therefore these two were correctly classified, at least for that subject in that particular situation.

The recommended index level for continuous physical work over an eight hour period is 40% of estimated aerobic capacity levels [8]. This level of estimated aerobic capacity is particularly important, as it is at this level, or below that a person can work continuously for an eight hour period without becoming fatigued [1, 4, 5, 13].

In the present study the mean relative heart rate (% HRR) for the pasture was 53% ± (3.7), for mounded it was 51% (± 7.8), and for the cutover it was 55% (± 5.5). These figures fall outside the recommended limits previously outlined, showing that the subjects were working at an unsustainably high rate and would be expected to be experiencing significant levels of residual fatigue. Since the task of planting is self-paced, with the incentive of high production rates equalling high financial reward, one could safely assume that the planters in this study exceeded their sustainable pace in order to obtain higher financial rewards.

In terms of tasks within the New Zealand forest industry, the mean relative heart rates were higher than first lift manual pruning Douglas Fir 29 ± 7% [8], motor-manual tree falling 32 ± 4.4% [11], breakingout 36 ± 3.1% [11], and second lift manual pruning Pinus radiata 39% [6].

As the % HRR is calculated for an eight hour day, measuring a shorter day will result in an over-estimate. As the planters, for the most part, worked a seven to eight hour day (plus one lunch break consisting of between 30 to 60 minutes), the % HRR's calculated here are not over-estimates.

The average ratio of working heart rate to resting heart rate was 2.2 (+ 0.2) for pasture, 2.1 (± 0.2) for mounded and 2.2 (± 0.1) for cutover. This ratio is higher than all tasks previously measured in the New Zealand forest industry, including first lift pruning of Douglas Fir 1.45 ± 0.08 [8], motor-manual tree falling 1.58 ± 0.1 [11], and breakingout 1.84 ± 0.11 [9].

It should be noted that the maximum heart rate was estimated by subtracting the subjects age from 220 [4]. Although this method contains some degree of error, the method has generally been accepted by researchers as a valid method, which can be easily used [4, 8, 22].

The use of the HR_w/50% level has been accepted as a simple and efficient way of estimating physical strain [8, 12]. If the resulting number is 1 or above, the work being monitored can be classified as hard continuous work [12]. In the current research, the means for all three sites exceeded 1 (pasture - 1.03, mounded - 1.01 and cutover - 1.06). Therefore, planting on all three sites can be classified as hard continuous work. This is higher than any other tasks measured in the New Zealand forest industry, including first lift pruning of Douglas Fir 0.82 [8], motor-manual tree falling 0.83 [11], and breakingout 0.85 [9].

The finding that the productivity was lowest on the site with the least favourable conditions (largest slope, strongest soil, heaviest boxes), and yet the mean heart rate was remarkably similar to the other two conditions, is in agreement with the Norwegian research [20], but disagrees with the Chilean research [2] and the pilot study [18]. Unfortunately, the Canadian study [19] did not separate terrain types. In the present study the planters compensated for the increased demands of planting on the pasture (steeper slopes, stronger soil and heavier boxes), by planting significantly less seedlings per hour. However, despite the mean HR_w for mounded being statistically ($P < 0.05$) lower than both pasture and cutover, the mean heart rates were approximately the same, as in the Norwegian research, and heart rate indices were all similar.

Therefore, the results of the pilot study [18] and the Chilean study [2] do not agree with the constant strain behaviour, while the Norwegian study and the present study support this phenomena. Consequently, further research is needed to clarify this issue and determine what has caused these divergent results.

The difference in the number of seedlings per box between the pasture site and the other two sites was stipulated by the forest company. The forest company requested that the planting boxes contained approximately 150 seedlings on the pasture site and 100 on the cutover and spot mounded sites. This difference was due mainly to the increased cost of transporting pods (crates containing approximately 60 planting boxes) to the pasture site, which did not have a developed forest road network. Therefore the number of seedlings per box was higher than on the two sites with an established forest road infrastructure.

Work activity

Across all three sites the majority of the day was spent planting, with one main rest break at the middle of the working day. Tables 4, 5 and 6 show that the rest breaks accounted for 11% on the pasture and 6.5% on the mounded site. There was no rest break recorded on the untreated cutover, due to the fact that the subjects worked the morning on the mounded site, had their lunch break and travelled to the cutover site, where they planted for the remainder of the day. This meant only two subjects could be studied for half a day each planting on the untreated cutover site. This decreases the confidence we have that the data collected at this site is indeed representative of planting on untreated cutover. The shift to the untreated cutover site was not planned by the researchers and is one of the problems associated with studying planters under standard production forestry conditions.

Hazards

The number of hazards per 100 seedlings planted was very low compared to other tasks measured within the New Zealand forest industry. The number of hazards recorded while felling under standard production forestry conditions was 15 hazards per 100 trees felled [11]. Felling wind damaged trees resulted in up to 83 hazards per 100 trees felled [10]. Both of these figures are substantially higher than the number of hazards recorded in the present study. However, planters can plant 100 seedlings in 30-45 minutes, while a faller would normally fell less than 100 trees in an 8 hour day. Therefore, using an hourly rate would allow a more valid comparison. In the current study the hourly hazard rate were 1.09/hr on the pasture, 0.56/hr on the mounded site and 0.25/hour on the untreated cutover. Unfortunately, neither of the other two studies provided enough data to convert their reported hazard rates into an hourly rate.

Body Part Discomfort

Planters did not report any discomfort while planting on mounded or cutover sites. On the pasture, discomfort was mentioned in 48% of all cases. The right (planting) elbow was the most frequently reported area of discomfort, followed by the mid-back. Possible reasons for discomfort only being found on the pasture include; the soil was significantly stronger (right elbow), the boxes were significantly heavier (mid back and hips) and the terrain

was significantly steeper (feet, ankles, lower leg). This graphically illustrates that planting under more difficult conditions (pasture) has a negative impact upon the planters body.

CONCLUSIONS

The various heart rate indices used during this study indicate that planting on all three sites can be classified as "hard continuous work" to "very heavy work". The three sites did not differ greatly, producing average working heart rates (± Standard Deviation) ranging from 132.7 bt.min^{-1}(± 16.2) to 134.9 bt.min^{-1} (± 13.8), a mean relative heart rate ranging from 51% (± 7.8) to 55% (± 5.5), a mean ratio of working heart rate to sleeping heart rate ranging from 2.1 (± 0.2) to 2.2 (± 0.2) and a mean 50% working heart rate level ranging from 1.01 (± 0.08) to 1.06 (± 0.06). Planters maintained similar mean working heart rates, for all three sites, by decreasing productivity as planting conditions became more difficult. Productivity on the untreated pasture was significantly lower than on the other two sites. To some extent, this was a result of the steeper slopes, heavier boxes and stronger soil. Body part discomfort was only experienced when planting on pasture, where slight to severe discomfort was reported 48% of the time. Hazard occurrence was low for all three site conditions, ranging from one hazard per hour (pasture) to one every four hours (untreated cutover). Slips accounted for 76% of all hazards, with hitting a solid object or the boot with the spade accounting for the rest.

ACKNOWLEDGMENTS

The authors thank the Forestry Corporation of New Zealand, Dean Lawson, and his crew for assistance.

AUTHOR'S CONTACT

The author can be reached by email at --
M.Sullman@massey.ac.nz

REFERENCES

[1] Apud, E., Bostrand, L., Mobbs, I.D. and Strehlke, B. 1989. Human biological methods for ergonomics research in forestry. In Guide-lines on Ergonomic Study in Forestry. International Labour Office: Geneva.

[2] Apud, E. and Valdes, S. 1994. Physical workload and output for planting on grounds with different slopes. In Proceedings of the International Seminar on Forest Operations Under Mountainous Conditions. J. Sessions (Ed.) FAO, Harbin.

[3] Åstrand, I. 1967. Degree of strain during building work as related to individual aerobic capacity. Ergonomics, 10, p293.

[4] Åstrand, P.O. and Rodahl, K. 1986. Textbook of Work Physiology. McGraw Hill: New York.

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

[6] Ford, D. 1995. An Ergonomic Analysis of Manual Versus Chainsaw High Ladder Pruning of Pinus radiata in New Zealand. A thesis submitted in partial fulfilment of the requirements of the degree of Master of Philosophy at Massey University.

[7] Hartsough, B. and Parker, R. 1997. Manual pruning of Douglas-Fir. New Zealand Journal of Forestry Science, 26, 449-459.

[8] Kirk, P. M., and Parker, R. J. 1996. An ergonomic evaluation of Douglas Fir manual pruning in New Zealand. Journal of Forest Engineering, 7(2), 51-58.

[9] Kirk, P., & Sullman, M. 1995. An Ergonomic Investigation of Hauler Breaker-outs. LIRO Project Report, 55.

[10] Kirk, P. and Sullman, M. 1996. Impacts of windthrow salvage on faller and breaker-out safety in cable logging operations. LIRO Report 21, 30.

[11] Kirk, P., Sullman, M. and Parker, R. 1996. The impact of fatigue on the safety, comfort and productivity of clearfell tree fallers. LIRO Report 21, 18.

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

[13] Levine, L., Evans, W., Winsmann, F.R. and Pandolf, K.B. 1982. Prolonged self-paced hard physical exercise comparing trained and untrained men. Ergonomics, 5 (5), 393-400.

[14] Minard, D., Goldsmith, R., Farrier Jr, P.H., and Lambiotte Jr, B.H. 1971. Physiological evaluation of industrial heat stress. American Industrial Hygiene Association Journal, 32, 17-28.

[15] Parsons, K.C. 1993. Human Thermal Environments. Taylor and Francis, London.

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

[17] Smith, L.A. and Rummer, R.B. 1988. Development of a heat stress prevention activity guide for use by southern forest harvesting managers. Final Report No. 19-87-065, USDA, Forest Service: New Orleans.

[18] Trewin, A.R.D. and Kirk, P.M. 1992. Planting bare-rooted seedlings of Radiata Pine on difficult terrain. Proceedings of Harvesting and Re-establishment of Difficult Terrain. LIRO, Rotorua.

[19] Trites, D.G., Robinson, D.G. and Banister, E.W. 1993. Cardiovascular and muscular strain during a tree planting season among British Columbia silviculture workers. Ergonomics, 36 (8), 935-949.

[20] Vik, T. 1984. Impact of terrain on human effort in forest operations. In Proceedings of Human Resources in Logging. LIRA, Rotorua.

[21] Vitalis, A. 1987. The use of heart rate as the main predictor of the cost of work. In proceedings of the Inaugural Conference of the New Zealand Ergonomics Society. Auckland, New Zealand.

[22] Vitalis, A., Pournaras, N.D., Jeffrey, G.B., Tsagarakis, G., Monastitiotis, G. and Kvvadiast, S. 1994. Heart rate strain in Greek steelworkers. Ergonomics, 21 (5), 845-850.