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The effect of fluid consumption on the forest workers' performance strategy

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Abstract

The heart rate development and time consumption of four Zimbabwean forest workers engaged in manual harvesting were studied to assess their performance strategy and whether this strategy was affected by differences in fluid consumption. Each worker was studied during eight consecutive working days and produced 2.4 m^3 pulpwood/day. They consumed either 0.17 l or 0.6 l of water each half hour with one fluid scheme assigned to each day according to a randomised block (person) design with four replicates (days). All workers were found to harvest large trees at the start of the working day and small trees at the end. All workers took longer to complete their task when on the low fluid scheme, however, the effect on the heart rate development varied for the individual workers as the strategies adopted to accommodate the stress inflicted by the low fluid scheme, varied for the individual workers. It is recommended that sufficient fluid supply during work is accompanied by training of the workers to convey the need and benefits of sufficient fluid consumption.

Key words: dehydration, behavioural choice, work physiology

1. Introduction

From a global perspective, a majority of forest workers are today still engaged in manual or motor-manual work activities. These activities are commonly described as being physically strenuous. Sullman and Byers (2000), for example, found that the mean working heart rate during manual planting in New Zealand exceeded 50% of the heart rate reserve, while Seixas and Ducatti (1995) found that forest workers in Brazil, producing pulpwood with chain saw and axe, exceeded 40% of their estimated cardiovascular capacity. Wigaeus Hjelm and Frisk (1985) found that forest workers in Vietnam (mainly women) performing harvesting and silvicultural activities with only hand tools, had a mean working heart rate that ranged from 38 to 69% of their heart rate reserve.

When physically strenuous work is performed, a large amount of excess heat is produced by the body and dissipated to the environment mainly by sweat evaporation (Parsons, 1993). As the need for heat dissipation calls for a redistribution of the blood flow, the venous return to the heart is reduced, leading to an increased heart rate (Hamilton et al., 1991). The sweating also leads to a reduced blood volume. During intensive physical exercise insufficient replacement of the excreted water and salts causes dehydration and adversely affects the person's physiological condition (Sawka, 1992). Wigaeus Hjelm and Frisk (1985) reported a weight loss of 3.2% per working day as the forest workers neither ate nor drank during the working time. In a study in British Colombia, Canada, Trites et al. (1993) attributed the mean weight decrease of 3.1% each day for planting workers mainly to dehydration. Paterson (1997) found a weight decrease of 1.2% for chain saw operators working in forestry in New Zealand on a voluntary drinking regime.

Dehydration has also been shown in a number of studies to reduce performance, as the reduced blood volume will lead to a reduced working capacity (Sawka, 1992; Fallowfield et al., 1996; Walsh et al., 1994; Below et al., 1995). In normal work practices this might lead to a reduced amount of work being done or an increase in time to perform a certain task.

Staal Wästerlund and Chaseling (2001) report a study on forest workers engaged in manual thinning operations in Zimbabwe. In this study, significant differences were found between the physiological as well as the labour-productive responses of the workers when exposed to a fluid consumption scheme leading to a mild level of dehydration as compared to a fluid consumption scheme securing full hydration throughout the work day. Over the full day's working period, which involved harvesting and debarking, workers on the fluid consumption scheme leading to a mild dehydration used, on average, a mean heart rate reserve of 39.9%, and had a mean body mass loss of 0.7 kg. When consuming the fluid consumption scheme securing full hydration, the same workers had a significantly lower mean heart rate reserve usage of only 36.6%, and a corresponding significantly higher mean body mass gain of 0.7 kg. The time to perform the task of producing 2.4 m^3 of pulpwood neatly stacked and debarked along the road side, was also found to be significantly higher during the days on the dehydrating fluid consumption scheme compared with days on the full hydration regime (234 min versus 209 min). As well as these overall effects, considerable variations were found in the responses of the individual forest workers, in particular during activities concerned with the harvesting of the trees. This raised the question of whether the performance differences found could be attributed solely to the differences in physiological responses, or if the effects found were accompanied by changes in the performance strategy.

According to Hockey (1997) the maintenance of performance under stressful conditions is an active mental process of managing resources controlled by the individual. His compensatory control model of performance regulation presupposes that individuals under stress either choose a "performance protection strategy" by maintaining performance at extra costs, or accept a reduction in performance. Adaptation of the work pace might be such an active managing process as was suggested by Smith et al. (1985) to explain the limited increase in heart rate in comparison to the considerable increase in temperature during the working days observed on chain saw operators in Southern USA during summer. Most work situations provide further possibilities for individuals to manage their physical workload. Since it is common in forest harvesting operations to assign a separate forest area to each worker to work in, possibilities for active management are provided in the choice of, for example, the size of the tree harvested next, the position of the tree harvested next, or the order in which trees are harvested.

This paper reports the further analysis of the results from the manual harvesting operation in Zimbabwe (Staal Wästerlund and Chaseling, 2001), with the specific objective of studying the performance strategies adopted during the harvesting component, by the forest workers engaged in the production of a prescribed volume in manual thinning operations under the two fluid regimes. In particular, it was of interest to determine whether or not there were differences in individual performance strategies, and to determine if the performance strategy was affected by differences in fluid consumption.

2. Material and methods

2.1 Test persons

Four male forest workers who had at least two years experience on the job, took part in the study. They were medically examined before the study. Their mean resting heart rate and mean maximum oxygen uptake capacity over the study days (VO_2max) were calculated from measurements taken each morning, and are presented in table 1 together with their age. The VO_2max was estimated at the work site using the steptest (Apud, 1989). The height of the step was 0.4 m and the frequency of stepping 22.5 times per minute. During work they wore a sturdy boiler suit, a safety helmet, shoes, socks and underwear. The food recall made each day revealed that the workers consumed three meals per day consisting of corn flour porridge with a relish of vegetables, fish, beans or chicken. They consumed one to three cups of tea per day besides the water that was provided during the study.

Insert table 1 here

2.2 Experimental site and task studied

The study was conducted in North East Zimbabwe in October 1996 and consisted of manual thinning of a 13 year old Pinus patula (pine) forest stand which had been thinned and pruned earlier. The task each worker performed was to produce enough stem sections to make one stack of pulpwood of 2.4 m^3 along the roadside. The workers were allotted strips of forest within the stand, each adjoining the road, where they performed the task independently of each other. Trees to be felled were marked. Each tree was felled and processed into stem sections of 2.4 m length, which were transported to the roadside separately. The distance over which the logs were transported varied between 0 and 20 metres. The ground was level with very little undergrowth. Each worker was responsible for his own tools. In resemblance to the normal working procedure, no prescribed rests were given and no food was consumed while working. The climatic conditions were recorded at 8-minute intervals with a Brüel & Kjær WBGT heat stress monitor type 1219. The minimum and maximum temperatures for each study day are given in table 2. As the task studied was conducted in the morning, which may have limited the effect of dehydration in the form of sweat throughout the study.

Insert table 2 here

2.3 Experimental design

Two fluid consumption schemes were compared using a randomised block (persons) design with four replicates (days). The fluid provided consisted of water without additives served at room temperature. For each individual, the fluid schemes were assigned at random to the eight available working days. Due to study limitations, only two workers could be studied at any one time, thus a total of 16 days were involved, with test persons A and B being studied on days 1 to 8 and test persons C and D on days 9 to 16. During the working day, each individual consumed water at half hourly intervals at the rate of either 0.17 l (low fluid consumption scheme) or 0.6 l (high fluid consumption scheme) depending on the treatment assigned. The fluid schemes were chosen in compliance with the recommendation of ILO (1992) to consume at least 5 l per day for heavy work in hot environments. The low fluid consumption scheme was chosen to assure dehydration yet avoid any risk for heat injuries as medical facilities were not available in the near vicinity of the study area. The high fluid consumption scheme was chosen to assure full hydration. Before work started each test person was given 0.5 l of water to obtain full hydration at the start of the study day.

2.4 Study procedure

Continuous time studies were made with a centi-minute stopwatch for the defined elements in the work cycles (table 3).

Insert table 3 here

The volume of the trees was determined in solid volume under bark (m^3) for each stem section using the mid-point diameter. The heart rate was recorded each minute with a Polar Sport Tester PE 3000. As a measure of exertion, the percentage of heart rate reserve (*HRres*) was determined according to Rodahl (1989) using the formula:

$$HRres = \frac{(HRwork - HRrest) * 100}{HR\max - HRrest} \quad (1)$$

HRwork was calculated as the mean heart rate during the harvesting period, while the individual’s maximum heart rate was estimated as *HRmax* = 220 – age (Rodahl, 1989). The resting heart rate (*HRrest*) was measured each morning before commencing work after a rest period of at least 10 minutes.

2.5 Statistical analysis

To compare the effects of the two fluid consumption schemes over the entire study day, analyses were carried out on the variables number of trees harvested, volume per tree, stems processed per tree and stems carried per tree, using an analysis of variance with fluid schemes and persons as factors, and days within as the error term. Of particular interest was the interaction between persons and fluid consumption scheme, as this provided a measure of possible variations in the strategies used by the individual workers.

As the work assignment was to produce a certain volume of pulpwood, the developments of heart rate and time consumption during the working day were determined against the percentage of volume that had been produced. Five consecutive volume classes (00 – 20%, 21 – 40%, 41 – 60%, 61 – 80%, 81 – 100%) were formed and the trees were distributed over the volume classes in their respective order and contribution to the volume produced. The individual work element times and mean heart rates for each tree were assigned to the volume class occupied by the particular tree. For trees whose volume spanned more than one volume class, the mean percentage of heart rate reserve was considered a component of both classes, and the individual work element times were allocated to the volume class indicated by their place in the sequential processing order. Where a single element started in one volume class and finished in the next, the time was allocated proportionately to the appropriate volume classes as illustrated in figure 1. The assumption was made that time spent on disturbance always occurred when the productive work elements were completed. The time for the work element hang has been included in the felling time. The effective time (E_0) per volume class has been defined as the sum of walking & preparation, felling (including hang), debranching, cross-cutting, and carrying.

Insert figure 1 here

The heart rate reserve per tree (%), the effective time (min), the time taken for each work element (min) and the number of trees per volume class were analysed using the generalised linear model given as (2).

$$\underline{y_{ijkl}} = \mu + \underline{f_i} + \underline{p_j} + \underline{(fp)_{ij}} + \underline{d(fp)_{ijk}} + \underline{v_l} + \underline{(fv)_{il}} + \underline{(vp)_{jl}} + \underline{\varepsilon_{ijkl}} \qquad (2)$$

where:

y_{ijkl} = the measurement in the lth volume class for the jth individual on the kth day receiving the ith fluid scheme, i=1,2; j=1, … ,4; k =1,2; l= 00-20, …. , 81 -100.

f_i = the direct effect of the ith fluid scheme tested using $(fp)_{ij}$ or the pooling of $(fp)_{ij}$ and $d(fp)_{ijk}$ when $(fp)_{ij}$ not significant;

p_j = the effect of the jth individual;

$(fp)_{ij}$ = the effect of the interaction between fluid scheme and individual;

$d(fp)_{ijk}$ = the effect of the kth day for the jth individual while on the ith fluid scheme - used as error for testing fp;

v_l = the effect of the lth volume class;

$(fv)_{il}$ = the effects of interaction between volume class and fluid scheme;

$(vp)_{jl}$ = the effects of interaction between volume class and individual;

ε_{ijkl} = the random variation associated with y_{ijkl}.

Where the interaction between individuals and fluid treatment was found to be significant, the significances were explored for each person to assess the differences in working strategy. Statistical differences at p-values of 0.05 and below were considered to be significant. All analyses were carried out using SAS statistical software (SAS Institute Inc, 1999).

3. Results

3.1 Physiological effects

All four test persons showed a significant decrease in percentage heart rate reserve as the harvesting work progressed through the five volume classes (figure 2). This effect was consistent for both fluid schemes, however, the response to the fluid schemes (figure 2) in each volume class and across the entire harvesting period (table 4), varied significantly for the four persons. The overall mean percentage heart rate reserve used for the low fluid regime when compared with the high, was significantly higher for persons A and B, significantly lower for person C, and not significantly different for person D.

Insert figure 2 and table 4

3.2 Production effects

No significant differences were seen for the fluid schemes with respect to number of trees produced throughout the entire harvesting task or the average volume per tree (table 4). However, the responses to the two fluid schemes for the number of stems produced and carried vary significantly for the four individual workers (table 4) with persons B and C having no differences between the means for the two fluid schemes, person A cutting and carrying significantly more on the low fluid scheme and person D cutting and carrying significantly less on the low fluid scheme.

There was an increasing trend across the five volume classes in the number of trees, implying that the trees became smaller as work progressed (figure 2). This general trend was consistent for both fluid schemes, however, there were two distinct patterns of development. For test persons A and C, the number of trees increased stepwise throughout the five volume classes, whereas for persons B and D, only the number of trees in the final volume class showed a significant increase. There was no significant difference between the fluid consumption schemes for the number of trees in any single volume class.

Mean times across the entire harvesting period for the different work elements and the effective time are given in table 5. The mean effective time was significantly greater for the low fluid scheme. Although each work element contributed towards the increased time on the low fluid scheme, only the time for cross-cutting was significant. This overall effect was consistent for all volume classes and individuals, however, for some work elements there were differences in the responses of individuals to the two fluid regimes as seen by the significant interaction between persons and fluid scheme (table 5). The time taken for debranching was not affected by the two fluid schemes except for test person C who had a significantly higher time when on the low fluid regime (table 4). A significant difference between the disturbance times for the two fluid schemes is seen for test person B but not for the others, although conflicting trends are apparent (table 4).

Regardless of fluid scheme, as harvesting progressed across the five volume classes there were significantly increasing trends in the effective time and in the time consumptions for cross-cutting, carrying and rest, but a significantly decreasing trend in the time consumed for felling (table 6). The times consumed for waling and preparation, debranching and disturbance tended to remain consistent as the work progressed.

4. Discussion

In figure 2, it is shown that regardless of fluid scheme, after an initial peak, the heart rate reserve decreased as work progressed while the number of trees to fill the volume class increased for all workers. As the power output required to harvest a tree is dependent on its size (Sundberg, 1960), the results suggest a general performance strategy adopted by all workers to start the working day with large trees and finish with small trees. The difference in strategy of working systematically downward in tree size (test persons A and C) compared to a more random approach (test persons B and D) does not seem to affect the development of the heart rate reserve in any consistent pattern. Sundberg (1941) and Kilander (1961) showed that for (motor-)manual harvesting of trees, the time consumption per cubic meter increased with decreasing size of the tree. This is also seen in this study where there is a significant increase in the effective time over the volume classes corresponding to decreasing tree sizes (table 6).

When pooled across test persons, the effective time and the time for cross-cutting are significantly higher for the fluid scheme leading to dehydration, with all other work cycle elements showing no difference in mean time between the two fluid schemes. The effect on the heart rate reserve, however, varied significantly between individual workers indicating that different strategies might have been used to deal with the dehydration. When the complete time profiles are considered together with the production variables and heart rate reserve (tables 4 and 5), it is seen that despite only a limited number of variables showing significant interactions between fluid scheme and person, different strategies appear to be being used by the four persons. Person D maintains the same times for all activities, and has the same heart rate reserve for both fluid schemes. He appears to obtain this by cutting and carrying fewer stems on the dehydrating fluid scheme compared to the hydrating fluid scheme. The only case of a reduced heart rate reserve on the dehydrating fluid scheme is seen in person C who harvested slightly smaller trees compared to the hydrating fluid scheme. His time taken for each work cycle element was higher on the dehydrating fluid scheme compared to the hydrating fluid scheme, with the time for de-branching being significantly higher. This is consistent with the findings of Sundberg (1960 and 1941) who suggested that the heart rate will be lower and the time per cubic meter higher for small trees, in particular for de-branching, as compared to large trees. Test persons A and B also have responses corresponding Sundberg (1960) in that their strategy of cutting slightly larger trees while on the dehydrating fluid scheme resulted in a corresponding elevation in their heart rate. However, their responses do not correspond to Sundberg (1941) as their strategy showed an opposite trend in the time consumption per cubic meter.

Table 4 revealed that the test persons carried less stem sections than they produced on both fluid regimes. By choosing trees close to the road or by directing the felling direction to the road, the workers were able to limit the amount of carrying. There is also an indication that test person C might have used this strategy more during the high fluid consumption scheme compared to the low (90% of stem sections carried on the low fluid scheme compared with 80% on the high).

As reported in Staal Wästerlund and Chaseling (2001), the high fluid consumption scheme resulted in a weight increase. Test person D expressed feelings of discomfort during the high fluid consumption scheme due to abdominal bloating. Such discomfort may be reflected in the increased time for disturbance for two of the test persons (table 4).

No interviews were carried out with the test persons on their performance strategy. Therefore, it cannot be determined with certainty if the trends in tree size changes and stem sections carried versus stem sections produced, were a result of an active choice by the test persons or a result of the forest stand conditions. It is obvious, however, that the conditions created by the two fluid consumption schemes were met in different ways by the four test persons. Psychological research has shown that decision making processes can be affected by the environmental conditions or the work being performed. Paas and Adam (1991) found that heavy physical work reduced the mental performance on decision tasks but improved the performance on perception tasks. Nygren (1997) found that decision making is dependent on the person’s "framing" of a problem, i.e. how he or she prefer to reason, and that different "framing" strategies also can lead to different performance strategies under stress. It seems therefore, of interest to study further the possible effect of fluid consumption on decision making in forest workers.

The consecutive volume classes were created to be able to compare the heart rate development and time consumption independently from the number of trees produced each day. The number of classes was determined by the number of trees harvested each day. In the analysis it was assumed that the random variations in heart rate and time consumption were independent for each volume class. This was considered justified as the time span per volume class consisted of at least 13 minutes. It was also assumed that the disturbance noted in the time study protocol always occurred after the tree was processed and carried to the roadside.

To calculate the percentage of heart rate reserve, the maximum heart rate is estimated using the age of the person. According to Apud (1989), a considerable error can be made using this estimate at the individual scheme. Its effect on the results presented here, should, however, be controlled by the randomised block (person) design which ensures that any systematic error which may occur for a given person is eliminated from the treatment effects by the statistical analysis.

The time studies were made by two trained work study persons who followed the same worker during the eight consecutive working days. No control was made for possible systematic differences between the two, however, again the structure of the randomised block design ensures any such effect is eliminated in the consideration of treatment effects.

5. Conclusions and Recommendations

All test persons showed a similar performance strategy of harvesting large trees first and small trees at the end of the task. This principal strategy was not changed by the workers as a result of the difference in fluid consumption schemes. However, the choice of tree size as well as the choice of position of the tree relative to the road or alternatively the usage of directional felling, did change between individual forest workers. There is, therefore, reason to believe that the conditions to which the workers were exposed by the different fluid consumption schemes, were met by the workers in different ways. It is recommended that the supply of sufficient fluid at work is accompanied by training of the workers to convey the need and benefits of sufficient fluid consumption.

6. Acknowledgements

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Figure 1. The assignment of the work elements to the volume classes. w: walking & preparation, f: felling, db: debarking, cr: crosscutting, ca: carrying, di: disturbance, r: rest.

Figure 2. The mean heart rate reserve (%) and the mean number of trees for each test person and volume class.

Figure 1

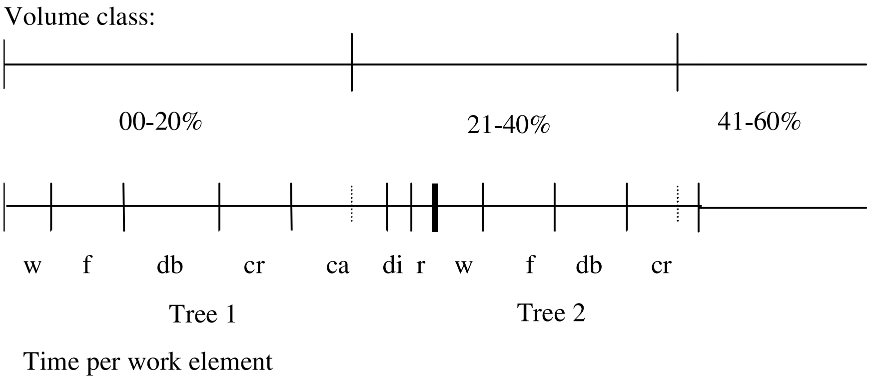
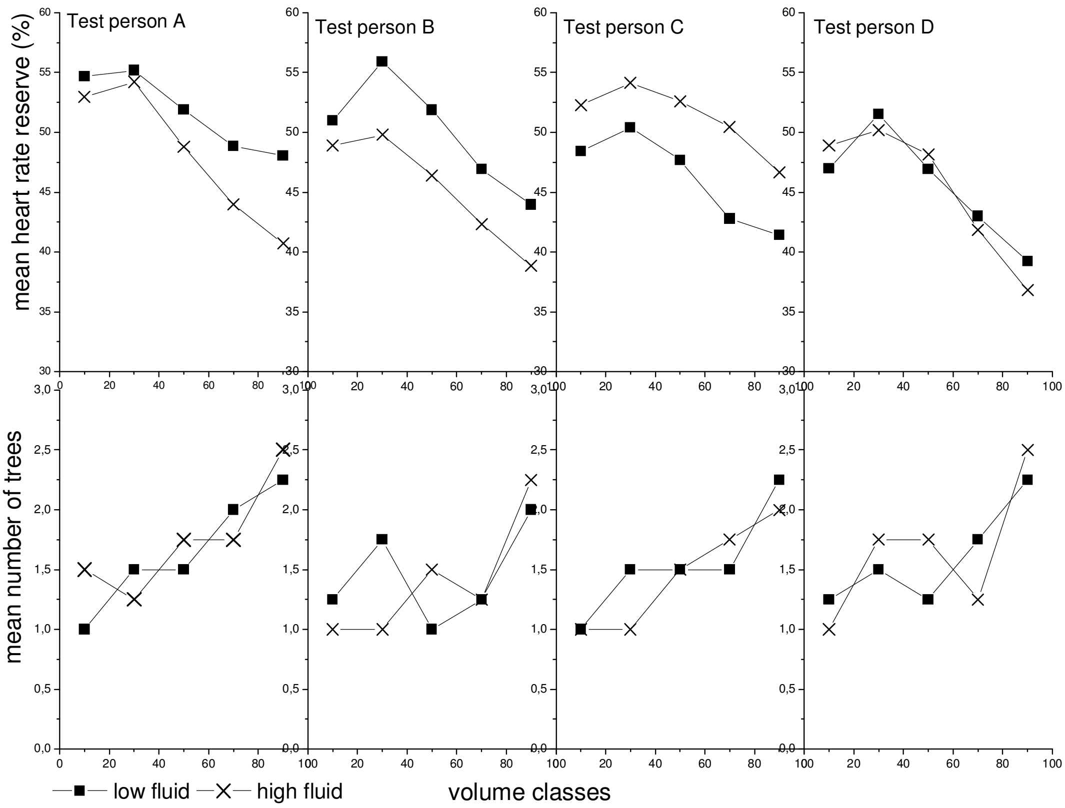

Volume class:
00-20%
21-40%
41-60%
w
f
db
cr
ca
di
r
w
f
db
cr
Tree 1
Tree 2
Time per work element

Figure 2.



mean heart rate reserve (%)
Test person A
Test person B
Test person C
Test person D
mean number of trees
low fluid
high fluid
volume classes

Table 1. Age, mean resting heart rate and mean VO_2max for the test persons.

test person	age (years)	resting heart rate (mean ± SD beats/min)	VO_2max (mean ± SD l/min)
A	20	68 ± 4.7	3.4 ± 0.34
B	28	66 ± 4.4	3.1 ± 0.25
C	40	60 ± 4.6	2.8 ± 0.19
D	24	64 ± 5.0	3.5 ± 0.19

Table 2. The minimum and maximum temperatures for each study day.

	Temperatures (° C WBGT)	
Study day	Minimum	Maximum
1	15.0	17.8
2	11.9	14.3
3	13.8	19.3
4	14.5	22.5
5	13.0	18.0
6	12.5	17.0
7	13.9	16.3
8	12.4	15.8
9	14.9	17.7
10	10.9	15.5
11	15.6	20.2
12	14.1	17.1
13	15.5	20.0
14	12.2	12.4
15	7.8	8.3
16	8.9	11.0

Table 3. Definitions and descriptions of the work cycle elements

Walking & preparation (w): begins at the moment the test person walks from the roadside into the stand. He collects his tools, walks around to select the next tree and clears undergrowth around the stem. The element ends when the axe is lifted for the first blow for the felling notch.
Felling (f): begins at the moment the test person has lifted the axe for the first blow for the felling notch. He makes the felling notch with the axe and the back cut with the handsaw. He pushes the tree over. The element ends when the tree hits the ground or the tree hangs in another tree.
Hang: begins at the moment the tree hangs in another tree and ends when the tree hits the ground.
De-branching (db): begins at the moment the tree hits the ground. The test person cuts off the branches with the axe. The element ends when the test person changes tools from axe to hand saw and measuring rod.
Cross-cutting (cr): begins at the moment the test person changes tools to hand saw and measuring rod. He measures and crosscuts the tree into stem sections. The element ends when the test person drops the hand saw after crosscutting the last stem section.
Carrying (ca): begins at the moment the test person drops the hand saw. He lifts a stem section on his shoulder, carries it to the roadside and returns to pick up the next stem section. The element ends when the last stem section drops on the ground at the roadside.
Disturbance (di): begins when a disturbance is encountered in any of the above mentioned elements and ends when the disturbance is over, e.g. a discussion with the supervisor, problem with tools, etc.
Study and rest (r): begins at the moment when the test person stops the productive work process for either study purposes (weighing & drinking) each half hour, or for recovering at self-chosen occasions. The element ends when the test person resumes productive work.

Table 4. Least squares means over the harvesting period for the percentage of heart rate reserve (HRres) used, the mean number of trees (trees) and volume/tree (vol/tree) produced, the mean number of stem sections produced/ tree (stempro) and carried/tree (stemcar). For a given variable, means in the same column with a letter in common are not significantly different at $p \leq 0.05$.

			Test persons				pooled across workers	interaction person*fluid
variable	unit	fluid scheme	A	B	C	D		
HRres	%	low	52.7a	49.7a	44.8a	45.7a	48.2a	$p < 0.01$
		high	50.4b	45.0b	50.6b	45.6a	47.9a	
trees	No	low	7.75a	6.75a	7.25a	7.75a	7.38a	NS
		high	8.00a	6.75a	6.25a	6.75a	6.94a	
vol/tree	m^3	low	0.206a	0.230a	0.223a	0.187a	0.211a	NS
		high	0.179a	0.211a	0.249a	0.210a	0.200a	
stempro	No	low	4.8a	5.0a	5.0a	4.4a	4.8a	$p < 0.01$
		high	4.2b	4.8a	5.0a	5.1b	4.8a	
stemcar	No	low	4.6a	4.1a	4.4a	3.3a	4.1a	$p < 0.01$
		high	3.9b	3.6a	4.0a	4.2b	3.9a	

Table 5. Time study results for the four individual test persons for the two fluid consumption schemes – values are mean time/volume class (min) for the indicated work elements Means in the same column with a letter in common are not significantly different at $p \leq 0.01$.

work cycle element	fluid scheme	Test Persons A	B	C	D	pooled across workers	interaction person*fluid
eff time	low	22.07a	21.78a	19.00a	19.10a	20.49a	NS
	high	18.99b	19.31a	16.57a	19.05a	18.48b	
walk & prep	low	1.79a	1.73a	1.16a	1.11a	1.45a	NS
	high	1.44a	1.36a	0.77a	1.31a	1.22a	
felling	low	5.20a	3.62a	3.14a	4.82a	4.20a	NS
	high	3.93a	3.95a	3.38a	4.53a	3.95a	
de-branching	low	3.43a	4.22a	5.40a	3.83a	4.22a	$p = 0.0349$
	high	4.14a	3.92a	4.01b	3.90a	3.99a	
cross-cut	low	5.92a	6.05a	6.04a	5.51a	5.88a	NS
	high	5.36a	5.49a	5.26a	5.19a	5.32b	
carry	low	5.74a	6.17a	3.25a	3.82a	4.74a	NS
	high	4.12b	4.59b	3.14a	4.12a	3.99a	
disturbance	low	2.21a	0.89b	1.83a	1.11a	1.51a	$p < 0.01$
	high	1.74a	2.38a	0.95a	1.44a	1.63a	
study & rest	low	2.60a	1.74a	1.27a	1.34a	1.74a	NS
	high	2.20a	1.38a	1.49a	1.83a	1.73a	

Table 6. Mean time/volume class (min) for the effective time and work elements for the five volume classes. Means in the same row with a letter in common are not significantly different at $p \leq 0.05$.

	volume class				
	00-20	21-40	41-60	61-80	81-100
effective time	17.55a	17.73a	20.58b	20.53b	21.02b
walking and preparation	1.23a	1.19a	1.45a	1.52a	1.28a
felling	5.13a	4.31ab	3.78b	3.67b	3.47b
de-branching	4.16a	3.87a	4.57a	4.16a	3.78a
crosscutting	4.96a	5.02ab	6.08c	5.84bc	6.11c
carrying	2.08a	3.34b	4.70c	5.34c	6.38d
disturbance	1.52a	1.59a	1.17a	1.30a	2.21a
rest	0.09a	1.09b	1.52b	2.65c	3.32c