International Ergonomic Workshop of IUFRO RG3.03: Ergonomic Challenges in Future Forest and Forestry, October 1-4, 2012, Nagoya, Japan

Workload Reduction for Younger and Older Workers with Synthetic Rope

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Key words: workload reduction, logging. synthetic rope

Abstract: *Describes research on workload reduction for logging workers replacing steel wire rope with synthetic rope in typical logging tasks. Over half of Oregon loggers are over age 45 and can benefit from improved materials. Research shows heart rate reductions for younger and older workers who replace steel rope with synthetic rope that weighs about 1/9 of steel yet is equally strong. Economic benefits are also documented even though synthetic rope is more costly. Future developments are outlined to further make improvements.*

1. Introduction

Forest operations are among the most important industries in many countries with worldwide roundwood removals valued at US $64 billion in 2005. Forests cover 30% of the globe's land area and employ 10 million people in forest management not including the processing facilities (FAO, 2005). Timber harvesting or logging starts the production cycle for forest products and has been characterized as difficult, dangerous dirty and declining (Garland, 2005). Nearly every year in the United States, logging is among the top three most dangerous jobs, and when all factors are considered, logging is likely the most dangerous job (US Department of Health & Human Services, 1999).

Early works by Åstrand and Rodahl (1986) and Rodahl (1989) characterize the physiology of work and note the heavy workloads found in logging tasks. Durnin and Passmore (1967) rate logging among the most exertive activities even compared to intense sports activities. Part of the exertion is due to the nature of the workplace and the tasks performed. On many logging sites, slopes are 30-100% (~17 to 45 degrees) in steepness. The terrain is covered with cut trees and logging slash thus workers are literally walking on wood (trees, logs, limbs, and underbrush). In Oregon and other logging states, more than 50% of the loggers are over age 45.

2. Logging Tasks and Methods

The tools and equipment for logging tasks are typically "heavy metal" to withstand the rigors of the work environment. Steel wire rope (SWR) is used universally in thousands of miles annually for logging but it is heavy, stiff and produces “jaggers” (broken wires that cause lacerations and painful puncture wounds). The mass per meter of length for the 10-35mm diameter steel wire ropes used are typically 0.39-5.22kg. The synthetic rope was either Amsteel Blue (Samson Rope) or Plasma (Puget Sound Rope) with essentially the same breaking strength as similar size wire rope but weighing 1/9 as much (mention of trade names is not an endorsement but their support is appreciated).

2.1 Tasks and Materials

For part of our research, standardized tasks using steel wire rope or synthetic rope were performed and data taken. The standardized tasks were designed to simulate activities encountered in both ground based skidding and steep slope cable yarding harvest processes including cable layout, rigging activities, and skidder line winching. The following activities were performed for heart rate monitoring and time measurement: carrying, dragging and pulling steel and synthetic rope on flat, moderate and steep terrain.

Rope types (16mm steel, 48.4m segment, 50.4kg; 16mm synthetic, 48.4m segment, 8.2kg, were used on standardized terrain on the Oregon State University Research Forest for all but four of the older workers subjects who were tested at their logging sites. Measures were taken for a length of 48.4 m on the pulling, carrying and dragging tasks.

2.2 Measurement

Heart rate data were collected using the Polar Advantage® monitoring and recording system (Polar Electro Oy, 1998). The Polar system consists of a monitoring strap worn around the chest and a wristwatch recording device. The chest strap senses the heart’s electrical impulses and transmits them to the wristwatch device. The wristwatch device receives the signals, displays continuous feedback, and stores heart rates at a selected interval. Heart rates (beats per minute, BPM) were recorded every five seconds. The time to complete each task element was compiled from the recorded heart rate – time relations and stopwatch comparisons.

2.3 Subjects

The younger workers in the study were part of OSU Research in 1999 and 2000 while the older workers were studied in 2010-2011. Workers self reported on their fitness level and the age is at the time the task was performed. Younger workers were paid for their participation, consented to participating in the evaluations and were free not to participate; older workers volunteered their performance or were paid by their employer. All subjects were covered by regulations of the university concerning human subjects and consent forms were signed. Conditions for the steel and synthetic rope trials were comparable but not exact. Table 1. shows the workers and their self-reported fitness assessment.

Table 1. Worker characteristics in the study

Worker	Age	Height (cm)	Mass (kg)	Fitness	Gender
1	23	175	79	good	M
2	21	168	59	good	F
3	25	185	91	good	M

4	23	193	118	good	M
5	38	196	102	good	M
6	22	175	59	good	F
7	47	178	75	good	M
8	46	178	75	good	M
9	23	173	70	good	M
10	21	178	75	good	M
11	38	188	75	excellent	M
12	22	180	75	good	M
13	20	169	70	good	F
20	49	196	114	excellent	M
21	51	183	84	good	M
22	62	180	100	excellent	M
23	43	180	75	excellent	M
24	43	180	75	excellent	M
25	60	185	95	excellent	M
27	46	173	73	excellent	M

The difference in fitness assessment for the workers is due in part to the student logging crew only working during summer while the older workers work the full year. Two females participated in the younger worker study.

2.4 Heart Rates and Time

Several heart rate measures were tested along with the time per task. Paired t-tests were used with a Po level of 0.05 for our significance of the test statistic.. We also hypothesized that the pattern of significant differences could be important as we would expect to find no significant differences between tasks that were quite easy (eg, pulling a line on a flat road) or where steel wire rope provides added momentum to worker performance (eg, steel wire rope actually pushing workers down a steep slope). For the standardized tests, the sample size was generally 13 or 7 workers, but for one or two tasks, a worker missed the task and the sample size was reduced .

2.41 Repeated Measures for Standard Tasks

We used each worker as his/her own control by performing the standard tasks including suitable rest periods. The sources of variation influencing logging tasks make it difficult to isolate differences of interest with small sample sizes.

2.42 Maximum Heart Rate

For each of the standardized tasks, the maximum heart rate for each subject was recorded for either steel wire rope or synthetic rope. Results were analyzed with a paired two-tail t-test using the Excel™ spreadsheet statistical function.

2.43 Heart Rate Reserve

We used a variant of the Heart Rate reserve (HRR) described by Åstrand and Rodahl (1986, p.496) and Rodahl (1989) which states:

One way of expressing the circulatory strain which a given work load imposes on a subject is to express the heart rate at the given work load as a percentage of the heart rate reserve of that particular individual (the heart rate reserve being the difference between maximal heart rate and resting heart rate)
{(HR task – HR rest) / (HR max – HR rest)} x 100% = HR reserve = HRR
(page 70)

We modified the formula for HRR by using the task's weighted average HR because our research was field-based. We used the rough approximation suggested by Åstrand and Rodahl (1986) as 220 minus age equaling the maximal heart rate. Our value for resting HR (lowest observed value for each worker) is adjusted by taking heart rates in the field. We believe logging workers use a portion of their HRR just being at the logging worksite with its uneven terrain and other environmental stimuli. For our comparison purposes to show the differences between steel and synthetic rope, we are comfortable with the modifications described above.

2.44 Heart Rate Recovery Rate (HRRR)

Shetler, et al (2001) acknowledge the use of heart rate recovery after a specified time to reflect fitness of individuals but also use the recovery rate to predict mortality in male populations. Forjaz et al (1998) document different exercise intensities produce different heart rates and recoveries in similar population of normotensive humans. The heart rate recovery rate is defined as the slope (rate of change) of the heart rate after task completion. Mathematically, the HRRR is the HR at end of task minus HR consistent with HR at task initiation with that difference divided by the elapsed time. Not all workers had heart rates that fully returned to pre-task levels; thus, we visually selected the heart rate slope interval. We report on what we think are differences in heart rate recovery rate related to task demands using steel or synthetic rope.

2.45 Time per Task

The stopwatch function of the heart rate measurement also provided a task time for each of the standardized tasks. Paired t-tests were used for testing differences.

3. Results

Figure 1. shows a typical comparative trace for a subject performing a task dragging the line downhill and then uphill. The time per task is available on the x-axis while heart rates show on the y-axis. Furthermore, the rate of change shows the heart rate recovery rate for the task segments.

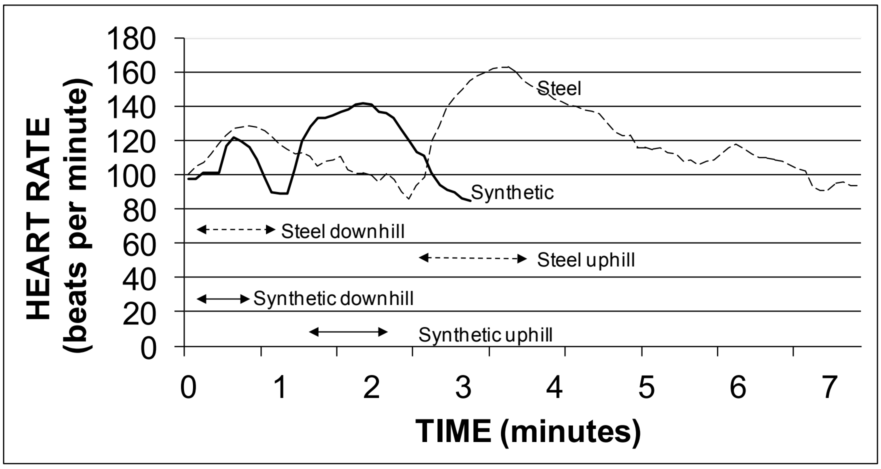

Figure 1. Heart rate trace for typical subject on downhill and uphill drag

3.1 Exemplary Results

There are too many individual results to show the differences for all task combinations. Table 3. shows results for one of the tasks for older workers: pulling line uphill on steep slopes.

Table 3. Task results for pulling line uphill on steep slopes for older workers

Task HR	max uphill pull steep		Task HR	Mean HRR	Task HRR	% HRR uphill pull
Worker	syn	steel	syn	steel	syn	steel
20	140	152	122	138	43%	62%
21	112	161	108	146	34%	75%
23	122	162	114	133	35%	63%
24	110	152	104	139	13%	55%
25	109	160	102	146	20%	67%
26	104	130	100	126	9%	48%
27	132	162	119	144	13%	52%
mean	118	154	110	139	24%	60%
0.000247049	Po	0.000150455	Po	3.02971E-05	Po	
Time task	max uphill pull steep		Heart Rate Recovery Rate			
Worker	syn	steel	syn	steel		
20	24	50	28	17		
21	48	90	29	15		
23	44	92	32	14		
24	40	110	27	19		
25	41	67	31	18		
26	45	60	24	12		
27	34	39	32	22		
mean	39	73	29	17		
0.003552261	Po	2.64706E-05	Po			

Overall Table 3 shows highly significant differences on a difficult task favoring synthetic rope. Moreover, notice the high maximum heart rates and the significant level of heart rate reserve utilized during the steel task. When we examine the total workers' heart rate recovery rate over all tasks, a pattern of differences emerges. For the moderately easy tasks, there are no significant differences between workers' recovery rates suggesting to us, little difference between steel and synthetic rope. Also where steel wire rope tends to "push" workers downhill, the difference is not significant. However, dragging the ropes on a slope or carrying ropes on a steep slope produce significant differences in heart rate recovery rates. The differences are due to the exertion required for the standardized tasks from the differences in the demands for steel wire rope or synthetic rope. For all workers, younger or older, the time per task favors synthetic over steel wire rope at significant levels. On difficult tasks, it took 2-6 times longer for the steel compared to synthetic rope

3.2 Subjective Measures

Subjective measures of differences between steel wire rope and synthetic rope were considered. The earlier research with younger workers and more recently with older workers emphasize that for moderately easy tasks, pulling, dragging or carrying line on flat terrain shows little difference compared to the difficult task on steep terrain. However, the experienced older workers remarked they felt more "sure-footed" with the synthetic rope compared to carrying or dragging steel wire rope.

3.3 Actual Logging Operations

Earlier research with younger workers was conducted on actual skidding operations. Data shows significance in the important sub-task of pulling winchline reducing time to 57%

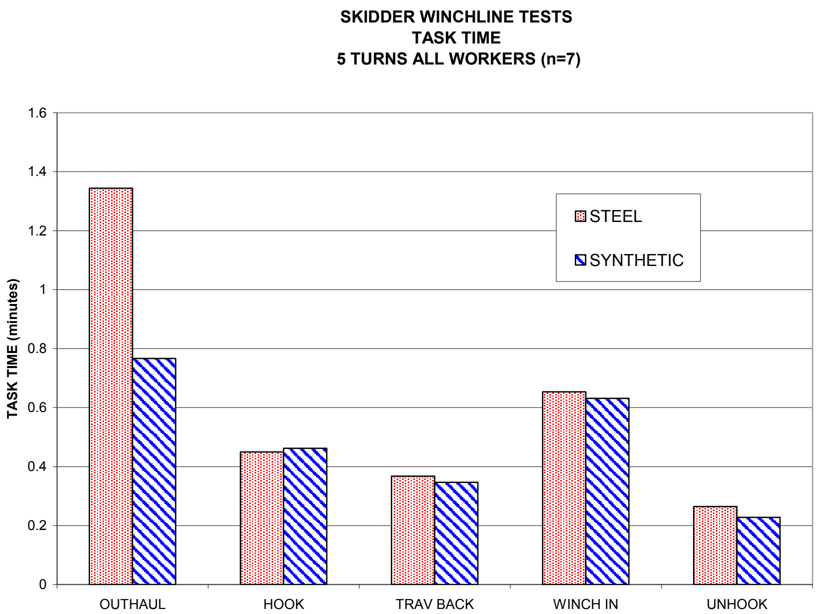

Figure 2. Mean time per activity on skidder winch line evaluation: 5 turns, 7 workers.

These results directly apply to actual logging operation but only for the younger workers. Resources did not allow similar tests for older workers.

4.0 Conclusions

By a number of measures, there are differences in task times and ergonomic values with heart rates to demonstrate benefits of synthetic rope over steel wire rope for both younger and older workers. Standard tasks similar to logging work activities were able to control environmental variation so rope differences could be shown by workers in paired t-tests. Time differences have significance for productivity and heart rate measures show lessened workloads. Maximal heart rate measures were higher for steel wire rope. There does not seem to be differences in the heart rate measures for older versus younger workers. Heart rate reserve differences are valid criteria; however, our modifications for the field research provide relative differences for rope material but not precise measures of individual heart rate reserve.

Fundamental research on workloads of older and younger workers reinforces the need to address measures to reduce those workloads in logging. Heart rate data encourages further trials and testing of synthetic rope to replace wire rope where feasible. Cost of synthetic rope is higher for initial purchase but benefits in productivity and to workers make it a useful material in logging. Further research is needed on new synthetic rope formulations and applications in logging.

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