A comparative analysis of neck muscle tension in a harvester operator compared with chainsaw and horse skidding operator and with normal human activities

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ABSTRACT: The goal of the experiment was to assess the physical stress experienced by an operator during the use of harvester equipment. Experimental data was obtained from field measurements with a Biofeedback 2000$^{x\text{-pert}}$ (BFB) unit, which allows recording of selected physiological parameters on the operator, especially an electromyogram of target muscle groups, body temperature, breathing rate and pulse. Experimental data was interpreted by comparing it with values measured during normal human activities. Measurements were done during logging using a harvester, a chainsaw, while skidding with a horse, while running, and while walking normally. The results of the experiment showed that the electromyograph (EMG) of the investigated muscle groups exhibited values 164% higher during running than during the cut-to-length (CTL) production, up to 77% higher while walking, up to 28% higher during logging with a chainsaw, and even up to 230% higher values while skidding with a horse. Body temperature and pulse measurements did not show a significant difference in values measured during CTL production and during other activities.

Keywords: biometric data; fatigue; harvester equipment; stress

Currently, the cut-to-length (CTL) method is the most modern and rapidly developing logging and transport method. At the same time, it offers a very effective alternative to motor-manual logging and skidding using traditional means, both from the aspect of timber production volume and from that of occupational health and safety. With the rapid development of harvesters and forwarders in the last 20 years, the number of machines used has been growing in Report on the Forestry of the Czech Republic (2011), along with demands placed on operators, both from the perspective of qualifications and from the aspect of physical health, mental and emotional abilities, and skills. Due to the fact that in some Northern European countries, CTL is used in over 90% of logging, in the USA 35–45% (Conradie et al. 2004) it can be presumed that the rapid growth in the number of used machines in Central and Eastern Europe will continue. Similarly, the demand for production optimization measures will also rise. The relatively complex and comprehensive operation of the machine along with the operator's high degree of responsibility for assets worth of millions of crowns places great demands on the operator's resistance to stress, while the pressure from environmental organizations cannot be ignored. Operators are exposed to an increased risk of spinal damage and chronic back and shoulder fatigue (Attebrant et al. 1997). It is precisely the back, shoulder and neck muscles that are most stressed during an operator's work (Axelsson, Ponton 1990). In comparison, Attebrant et al. (1997) stated that the greatest stress is present in arms and shoulders, because they have up to a 95% share in the total work done by an operator's musculature in controlling the machine. Miranda et al. (2001) proved that the physical condition of forestry workers, including logging and transport machine operators, significantly affects both their performance and work injuries and work-related illnesses. Miranda et al. (2001) stated that for example in the case of active athletes, it is possible to show a significantly smaller share of work injuries, and especially chronic pain of the back, pelvic muscles and arm and shoulder muscles. Stress caused by vibrations (Hagberg 2002) is also an important part of the stress interface.

Of course, equipment manufacturers are constantly trying to develop new equipment that increases the ergonomics of production, for example ergonomic arm and wrist rests, used in modern machines, along with balanced control elements that reduce stress on the operator's hand musculature by up to 60% (Attebrant et al. 1997).

A mental stress factor that cannot be ignored is irregularity of shifts. An irregular sleep schedule can cause sleep disturbances and thus increase the risk of work injuries (Santhi et al. 2005). Mitchell et al. (2008) confirmed the negative effects of a 24-hour work schedule on operator health, mental wellness and work efficiency.

The aim of the experiment was to evaluate the differences in selected physiological parameters of operators during CTL and chainsaw wood logging, skidding timber with a horse and in normal human activities – walking and running. The experiment is based on a series of measurements which were taken at the Faculty of Forestry and Wood Sciences, Czech University of Life Sciences.

MATERIAL AND METHODS

Measurements using BFB are relatively difficult in the logging environment, especially due to weather variability, difficult terrain and demanding work conditions. Precise BFB sensor placement, which is crucial for obtaining relevant data, is also difficult in the logging environment due to the short sensor signal to computer transmission range.

Placement of sensors registering temperature and pulse in the temple area is relatively straightforward thanks to a flexible headband that holds the sensors on the head, in this case in the *os temporale* location, specifically the *pars pyramidalis*.

Placement of electromyograph (EMG) sensors depends on the correct identification of the termination of muscle groups under assessment. In the experiment, bipolar placement was chosen, meaning a pair of identically coloured sensors for each half of the body (axially along the spine).

The first sensor (EMG 1) was located on the *musculus sternocleidomasteus* in the *processus mastoideus*, the second (EMG 2) on the *musculus trapesius* at the *clavicula* attachment point.

The reference electrode was always placed on the spine in the location of the *vertebrae cervicales* (C5, C6). The design of the application of the BFB for the purpose of this experiment and the base for it were described in Macků (2011). The right positioning of the sensors is illustrated in Fig. 1.

Measurements during harvester logging were performed using a Rottne 5005 machine (ROTTNE IMDUSTRI AB, Rottne, Sweeden), a high-performance class machine (above 140 kW). Two selected operators (A, B) were aged 35 and 42, with more than three years of practical experience.

Logging with a Husqvarna 576 (Husquarna, Stockholm, Sweeden) chainsaw was performed by a lumberjack aged 29 with ten years of experience.

A driver skidding timber with a horse was 34 years old with fourteen years of experience with an 8-year-old Silesian Norik horse.

RESULTS

During the experiment, over 130,000 EMG, temperature and pulse values were measured on two harvester operators, on a lumberjack while

Fig. 1. Positioning of the EMG sensors

logging with a chainsaw, and a driver skidding timber with a horse.

Measurements were done during four working shifts for each of the two harvester operators (A and B), during two working shifts for an operator while skidding timber with a horse and during two working shifts for an operator while logging wood with a chainsaw. Measurements during running and walking were realised by twenty-minute blocks, attended by harvester operator A. The data was then compared with the values obtained from one harvester operator while walking and running, so that biometric data for individual activities could be assessed. The values were then processed – Table 1 lists average, maximum and minimum values. For an easy assessment of differences in physiological parameters for individual activities, the percentage share of the average value for each biometric datum was calculated relative to the average of the same biometric value measured for harvester operators A and B. For example, if EMG 1 exhibits an increase of 215% in the case of the operator while skidding timber with a horse compared to EMG 1 of the harvester operator, Table 2 contains the value of 315%. The results are shown in Tables 2.

Under the given conditions, it was possible to prove that EMG values in specific muscle groups of a harvester operator are lower than while logging with a chainsaw, skidding timber with a horse, while walking, and while running.

Logging with a chainsaw exhibited values 138.09% higher on EMG 1 sensor and 218.88% higher on EMG 2 sensor compared to values measured on

Table 1. Values of physiological parameters for individual measured activities

Parameter	EMG 1 (μV)	EMG 2 (μV)	Temperature (°C)	Pulse (bpm)
Operator A				
Mean	17.2775	44.5796	34.4304	49.5563
Min	4.6661	9.0315	34.2650	48.6121
Max	92.1944	196.6201	34.5000	82.1381
Operator B				
Mean	19.4285	55.3337	34.2421	49.5554
Min	5.2881	10.3286	34.0800	34.1062
Max	124.9657	250.0000	34.4800	82.7979
Running				
Mean	24.5432	117.4236	34.1509	49.7760
Min	7.6687	16.2960	33.9800	33.5107
Max	108.2007	206.0966	34.3000	79.4883
Walking				
Mean	17.9370	78.7529	34.0290	49.5575
Min	7.6773	20.1783	33.7800	30.0244
Max	265.5093	493.0569	34.6800	84.7131
Coachman				
Mean	45.6608	147.4120	34.3962	49.5691
Min	5.3681	21.2447	33.6500	32,5427
Max	485.6042	500.0000	34.8700	90.2106
Woodcutter				
Mean	41.1186	142.1570	34.0662	49.5561
Min	7.7166	25.8723	33.7500	31.0474
Max	336.2730	500.0000	34.3000	79.7254

operator A and B – harvester operators, coachman – horse operator, woodcutter – chainsaw operator; EMG 1, EMG 2 – pair of electromyographs, temperature – body temperature of operators, pulse – blood volume pulse of operators, mean – arithmetic mean of measured values, min – minimum of measured values, max – maximum of measured values

Table 2. Percentage share of mean values of harvester operator A and B relative to the other measured activities

	EMG 1	EMG 2	Temp	Pulse
Operator A				
Running	142.12	263.40	99.18	100.43
Walking	103.86	176.66	98.83	100.00
Skidding	264.28	330.67	99.90	100.02
Cutting	238.09	318.88	98.94	100.00
Operator B				
Running	126.33	212.21	99.73	100.44
Walking	92.32	142.32	99.38	100.00
Skidding	235.02	266.41	100.45	100.02
Cutting	211.64	256.91	99.49	100.00

operator A and B – harvester operators, EMG 1, EMG 2 – pair of electromyographs, temp – body temperature of operators, pulse – blood volume pulse of operators

operator A. In comparison with the values for operator B, EMG 1 showed an 11.64% increase, and EMG 2 a 156.91% increase. The results of EMG 1 and 2 during horse skidding measurement showed increases of 164.208% and 218.88% compared to the results of operator A and of 111.64% and 156.91% compared to operator B. EMG values from measurements while running were 42.12% and 163.40% higher than for operator A and 26.33% and 112.21% higher than for B. EMG values from measurements while walking were 3.86% and 76.66% higher than for operator A. Compared to operator B, EMG 1 results were 7.68% lower, while values on EMG 2 sensor were 42.32% higher. Student's *t*-test was used for statistical analysis.

Results of the test showed a statistically significant difference between all EMG values comparing the harvester and the other activities (Table 3) as can be seen for the chosen sig. $P < 0.01$ and the corresponding critical value 2.576.

Student's *t*-test can confirm a positive result in all cases. Due to the high levels it can be said that the test error probability approaches zero. Data sets were tested for equality of variances using Levene's test for the chosen sig. $P < 0.05$, the homoscedasticity has been proved in all cases.

DISCUSSION

The aim of the experiment was to evaluate differences in selected physiological parameters, such as EMG, temperature and pulse of operators of harvester and chainsaw, operator of horse while skidding timber and in normal human activities – walking and running.

The experiment showed that under given conditions there was a difference in EMG values in all cases. Student's *t*-statistics confirmed a statistically significant difference between all EMG values comparing the harvester and the other activities. In the case of pulse and temperature, it showed that these parameters are not conclusive for the purpose of the experiment. For this reason, these parameters were not subjected to statistical analysis. Findings of the experiment are only partial and must be seen as a starting point for further research.

Table 3. Student's *t*-test values and error probability, comparison of the measured EMG values of two harvester operators with the EMG values measured during other activities ($P < 0.001$)

EMG 1	*t*-value	EMG 2	*t*-value
Operator A			
Harv A vs. Running	95.594	Harv A vs. Running	318.080
Harv A vs. Walking	7.554	Harv A vs. Walking	182.522
Harv A vs. Coachman	129.652	Harv A vs. Coachman	182.686
Harv A vs Chainsaw	124.357	Harv A vs. Chainsaw	166.683
Operator B			
Harv B vs. Running	36.660	Harv B vs. Running	120.197
Harv B vs. Walking	14.922	Harv B vs. Walking	90.533
Harv B vs. Coachman	114.637	Harv B vs. Coachman	154.299
Harv B vs Chainsaw	112.849	Harv B vs Chainsaw	143.510

EMG 1, EMG 2 – pair of electromyographs, Harv A – harvester operator A, Harv B – harvester operator B

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