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Analysis of postural strain of loggers during timber harvesting in a spruce stand

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Abstract: Motor-manual felling is the most common way of timber harvesting in Poland. This method of working exposes chainsaw operators to high ergonomic risk factors. One of the most significant of these is forced working postures. Research was carried out on two loggers working in a felling-age spruce stand. Over two consecutive days, video documentation was made, which was then analyzed using a computerized version of the OWAS method – WinOWAS. Based on 874 observations (467 for logger 1 and 407 for logger 2) the postures occurring were assigned respectively to 40 and 33 different codes. The codes most frequently recorded were 2121, 2131, 4131, 1171, 4121 and 1121. Postures in categories III and IV occupied 32.5% of the working shift in the case of logger 1, and 27.3% in the case of logger 2. Static strain for both loggers was found to be medium. The loggers worked most of the time with their backs bent forward. This back position was most common during felling (79.7% for logger 1, 62.6% for logger 2). Working postures showed more variation in the case of the legs. Acceptable postures, such as standing on straight legs, accounted for more than 40% of all leg positions.

Key words: timber harvesting, chainsaw operator, OWAS method, postural strain, working postures

INTRODUCTION

Timber harvesting volume in Poland is currently about 38 million m^3 annually (Forestry 2014). Despite constant technical progress towards replacing human labor with machines in case of particularly difficult and hazardous work, it is estimated that still over 80% of timber is harvested with the use of hand-operated machines. This means that the Polish forestry industry relies on loggers operating chainsaws, who are estimated to number 10,000 in total (Grzywiński 2011). These workers are exposed to hazardous working conditions due to many risk factors. Their work requires a great deal of physical strength and the adoption of forced, awkward postures (Hagen 1990, Harstela 1990, Grzywiński 2004, 2011). Additionally, operators are exposed to noise and vibration factors (Sowa 1995, 1998) and unfavorable weather conditions. Combined, these factors contribute to the development of musculoskeletal disorders (Hildebrandt et al. 2002).

The work of a logger requires a great deal of physical effort, generating high energy consumption, very often above the recommended net value of 8400 kJ (2000 kcal) (Fibiger 1976, Grzywiński 2004, 2010). Prolonged body strain resulting from excessive physical effort may lead to permanent musculoskeletal degeneration and extreme exhaustion (Jaworski 2008).

A very significant factor influencing the onerousness of the work of loggers operating chainsaws, apart from energy consumption, is forced posture while performing work and the associated static strains (Hagen et al. 1998, Grzywiński 2005, Zanuttini et al. 2005). Due to the forced postures, the generation and application of significant forces, and exposure to vibrations, logging is associated with a high risk of musculoskeletal disorders (MSDs). Recurring musculoskeletal pain might cause reflex posture changes, leading to distortion of body coordination and stability, thus increasing the risk of accident. Timber harvesting is the branch of forest industry where the most accidents take place, mainly affecting loggers (Grzywiński et al. 2013).

Body posture and movements are commonly evaluated using the following observation methods: OWAS – Ovako Working Posture Analysis System (Karhu et al. 1977), RULA – Rapid Upper Limb Assessment (McAtamney and Corlett 1993), and REBA – Rapid Entire Body Assessment (Hignett and McAtamney 2000). Static strain in the case of loggers evaluated using the OWAS method was part of a multidimensional risk assessment of loggers' work during timber harvesting in a mountainous environment (Leszczyński 2006, Leszczyński and Jałowska 2011). Zanuttini et al. (2005) used the OWAS method to evaluate musculoskeletal strain in loggers working in mountains and on a poplar plantation, finding a higher level of strain in the mountainous environment as a result of working on slopes. In turn, Stempski (2008, 2009) used the OWAS method to evaluate the static strain of chainsaw operators during clearcutting and thinning of pine stands, finding that in both types of cutting, strain categories I and II (allowable and nearly allowable strains) were predominant. The OWAS method was also used by Grzywiński and Łukaszuk (2008) to evaluate the postural strain of a logger working with an assistant in a pre-felling-age pine stand, indicating the use of a large variety

of postures, particularly the squatting position. Grzywiński and Bujnowska (2009) applied the OWAS method in their analysis of static strain of loggers during work in a beech stands, including early and late thinning and clearcutting. The authors found that working postures vary the most during early thinning, while category III and IV (high and very high strain on the musculoskeletal system) were more frequent during thinning than clearcutting.

The results of research show that changes in the design of chainsaws and reduction of their weight have not had a significant impact on postural strain and the risk of musculoskeletal disorders in loggers. Considering that motor-manual timber harvesting will continue to play a significant role, new solutions should be sought at the technological and organizational levels to improve the working conditions of chainsaw operators in timber harvesting (Giefing 1996, Grzywiński 2004).

The working postures of a chainsaw operator is one of the key ergonomic risk factors, due to its often forced, awkward nature and possible health consequences. The aim of this work is to evaluate the postural strain to which loggers are subjected during clearcutting in a spruce stand.

MATERIAL AND METHODS

1. CHARACTERISTICS OF WORKERS AND TREE STAND

The research subjects were two experienced loggers, carrying out clearcuttings in spruce stand in Karnieszewice Forestry District, RDLP Szczecinek. Table 1 contains the characteristics of these workers. Both loggers worked in the same stand.

Table 1. Anthropometric characteristics of the loggers

Features	Logger 1	Logger 2
Age (years)	45	51
Height (cm)	172	168
Body mass (kg)	96	70
BMI (kg/m^2)	32,4	24,8
Total work experience (years)	21	22
Work experience as a logger (years)	21	21

The harvested stand was 90 years old, with an average height of 21 meters and an average tree diameter at 1.30 m of 23 cm (Opis taksacyjny 2007). Timber harvesting was performed using a long wood system. The loggers performed the work (felling, delimbing, bucking) individually without assistance. They measured the logs and rollers with a self-retracting measuring tape. Logs were transported after the loggers had finished work within their working areas. Logger 1 used a Stihl MS 361, 3.4 kW, weighing 7.0 kg without fuel, and 7.8 kg when filled with fuel. Logger 2 used a Husqvarna 346 XP, 2.7 kW, also weighing 7.0 kg without fuel, and 7.5 kg when filled. The research was conducted during two consecutive working days in spring. The average temperature on the first day was 10°C, with a weak to moderate southeasterly wind (10–20 km/h), heavy clouds and no rain. The average temperature on the second day was 14°C, with a weak to moderate northwesterly wind (10–20 km/h), moderate cloud cover and showers.

2. METHODS

Postural strain was evaluated using the OWAS (Ovako Working Posture Analysis System) method (Karhu et al. 1977). This makes it possible to perform a comprehensive postural evaluation, and is used in research carried out directly at the workplace. It was developed in the 1970s by researchers from the Institute for Labor Protection, Finland, and academic staff at Ovako Steelworks. OWAS method includes postural evaluation of three body segments (back, arms, legs) and the external force value (Fig. 1). Each posture is described with a four digit code, defining back position (four variants), arm position (three variants), leg position (seven variants) and external force value (three variants).

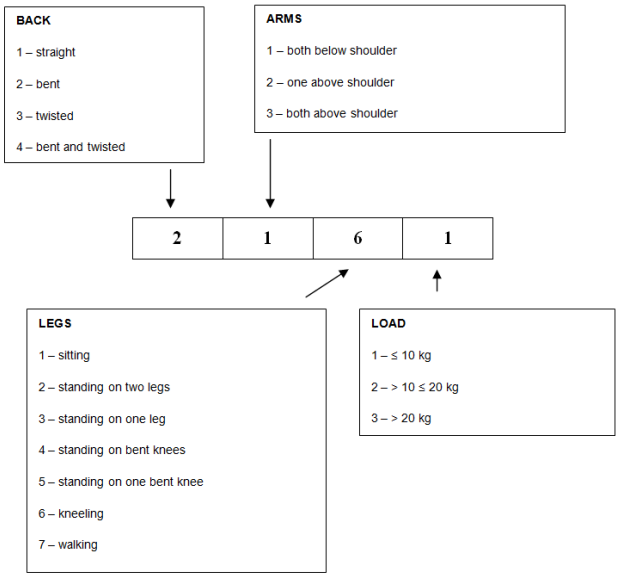

Fig. 1. Classification of back, arms, legs position and external load (WinOWAS, 1996)

Based on the code, each position is assigned to one of the four OWAS categories (I is low, IV is high) defining the strain value, the influence the position has on the musculoskeletal system, and further actions that should be taken at the place of working.

Posture codification and assignment of OWAS strain categories was performed using a computerized version of OWAS – the WinOWAS software (WinOWAS 1996, ©

Tampere University of Technology, Finland). The analysis was based on video material covering two working days of each logger. The material was analyzed in 30-second intervals.

RESULTS

Based on the video material, a total of 874 observations were recorded during clearcutting in a spruce stand (467 for logger 1 and 407 for logger 2). The postures adopted by logger 1 were assigned 40 different codes, while those of logger 2 were assigned 33 different codes (Table 2). The codes most frequently recorded were 2121, 2131, 4131, 1171, 4121 and 1121.

WinOWAS automatically assigns posture codes to appropriate strain categories based on the degree to which the postures are forced. Both loggers adopted category II (nearly allowable) positions for 50% of the time. Logger 1 adopted category III positions, characterized by high static strain, for 12.2% of the working time, while for another 9.2% of the time he adopted category IV positions, characterized by very high strain on the musculoskeletal system (Table 2).In total, category III and IV positions accounted for 21.4% of the working shift. Logger 2 adopted category III and IV positions for 15.7% of his shift (category III – 8.8%, category IV – 7.9%). Based on the percentages for each OWAS category, the overall static

Table 2. The share (%) of working postures in OWAS categories

OWAS category	Logger 1			Logger 2		
	Posture code	Number of observations	%	Posture code	Number of observations	%
1	1121	31	6.6	1171	28	6.9
	1171	30	6.4	1131	27	6.6
	1131	19	4.1	1121	22	5.4
	1161	10	2.1	3121	19	4.7
	3131	9	1.9	3131	14	3.4
	1221	8	1.7	1161	9	2.2
	3121	8	1.7	3161	3	0.7
	1231	6	1.3	1111	2	0.5
	others	10	2.1	others	11	2.7
	Total	131	28.1	Total	135	33.2
2	2121	80	17.1	2121	60	14.7
	2131	50	10.7	2131	47	11.5
	4121	29	6.2	4131	36	8.8
	4131	28	6.0	4121	27	6.6
	2161	15	3.2	2161	25	6.1
	1141	10	2.1	1151	4	1.0
	2171	8	1.7	1141	2	0.5
	2221	7	1.5	1341	1	0.2
	others	9	1.9	others	2	0.5
	Total	236	50.5	Total	204	50.1
3	2141	25	5.4	2141	18	4.4
	2151	15	3.2	2151	11	2.7
	2261	6	1.3	3141	2	0.5
	3141	6	1.3	2241	1	0.2
	others	5	1.1	others	0	0.0
	Total	57	12.2	Total	32	7.9
4	4141	21	4.5	4151	21	5.2
	4151	11	2.4	4141	10	2.5
	3151	6	1.3	4161	3	0.7
	others	5	1.1	others	2	0.5
	Total	43	9.2	Total	36	8.8
Total		467	100		407	100

strain of the loggers was classified as medium. Figure 2 shows category III and IV frequencies during particular activities.

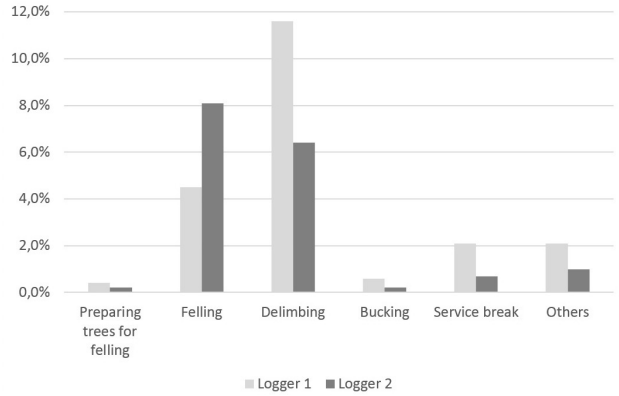

Fig. 2. The share (%) of working postures classified to III and IV category in particular work activities

Table 3 shows the percentages for the positions of each body segment during the main timber harvesting operations using the chainsaw. The most frequent postures during felling were those with a bent back (79.1% for logger 1, 62.6% for logger 2). Positions with bent and twisted back accounted for 8.4% (logger 1) and 28.9% (logger 2). During delimbing, logger 1 worked 38.7% of the time with his back bent forward and 31.9% with bent and twisted back; for logger 2 the respective percentages were 38.1% and 24.8%. During bucking, logger 1 worked 49.9% of the time with his back bent forward and 29.5% with a bent and twisted back; the figures for logger 2 were 60.7% and 24.9%. Postures with the bent back or bent and twisted at the same time are classified as high ergonomic risk postures.

Most operations were performed on straight legs. The proportion of time accounted for by such positions ranged in the case of the first logger from 38.8% (delimbing) to 52.9% (log cutting), and in the case of the second logger from 37.4% (felling) to 46.4% (bucking). The second most frequent posture type was with one leg straight (with shifting of body weight). The percentage for this type ranged from 22.6% to 38.3% (logger 1) or from 22.9% to 46.4% (logger 2). Postures with both legs bent were similarly predominant during felling, with percentages of 19.1% and 15.6% respectively. Logger 1 worked on bent legs equally often (17.9%) while delimbing.

DISCUSSION

The posture adopted most frequently by both loggers was that with code 2121 – bent back, both arms below the shoulder joint, legs straight, external load below 10 kg. This was universal enough to be adopted during felling, delimbing as well as bucking. The predominance of code 2121 (approximately 16% over a whole day) is consistent with the results of Grzywiński et al. (2005) and Grzywiński (2011), who found the standing posture on straight legs, or bent at the knees, to be the most frequently adopted by loggers. Grzywiński and Bujnowska (2009) observed loggers during thinning and final cutting in beech stands, finding four codes to be dominant, including 2121 (the second most frequent code). The present research indicates a large variety of adopted postures (40 codes for logger 1, 33 codes for logger 2); however, a significant number of them are used only incidentally. Grzywiński (2011) conducted postural strain research on a group of 41 loggers, finding that they adopted 54 different postures, of which the four most frequent accounted for more than 50% of the total working time.

Table 3. The share (%) of specific position of back, arms and legs in main activities during motor-manual timber harvesting

Body segment	Felling		Delimbing		Bucking	
	Logger 1	Logger 2	Logger 1	Logger 2	Logger 1	Logger 2
BACK						
straight	10.7	7.3	18.6	21.8	17.6	10.8
bent	79.7	62.6	38.7	38.1	49.9	60.7
twisted	1.2	1.2	10.8	15.3	3.0	3.6
bent and twisted	8.4	28.9	31.9	24.8	29.5	24.9
ARMS						
both below shoulder	94.0	98.8	93.9	98.0	94.2	92.8
one above shoulder	3.6	1.2	5.7	2	5.8	7.2
both above shoulder	2.4	-	0.4	-	-	-
LEGS						
standing on two legs	45.1	37.4	38.8	40.4	52.9	46.4
standing on one leg	22.6	22.9	31.6	43.4	38.3	46.4
standing on two bent knees	19.1	15.6	17.9	8.9	5.9	3.6
standing on one bent knee	6.0	24.1	9.5	6.8	2.9	3.6
kneeling	7.2	-	-	0.5	-	-
walking	-	-	2.2	-	-	-

The static strain of the loggers during clearcutting in spruce stand was classified as medium. The defining factor for this classification was the proportion of time accounted for by categories III and IV (high and very high

musculoskeletal strain), respectively 32.5% and 27.3% of the working shift. Ostrowski (2009), who studied the harvesting of felling-age beech forest, and Stefański (2009), who analyzed the static strain of loggers harvesting felling-age pine forest, both obtained similar results. However, Ziemann (2011), who studied the static strain of a logger with 21 years of experience, working in a felling-age spruce stand, found that categories III and IV (high strain) comprised as much as 60%. The differences in observations are in line with the suggestion of Grzywiński (2011) that interpersonal differences and the variety of working techniques have a significant influence on the adoption of different body positions during work. This assumes that incorrect but established routines may play a significant role in the case of workers with long professional experience. Paluch (2005) arrived at similar conclusions, identifying habits as the main factor behind differences in working posture.

Noteworthy is the significant percentage of postures with the back bent forward or twisted, or both at the same time. For about 85% of the time spent on felling, delimbing and bucking, the loggers adopted positions categorized as high ergonomic risk postures. The working postures varied more in the case of the legs. Acceptable leg positions, such as standing on straight legs, accounted for more than 40% of all leg positions. The small percentage of kneeling postures was an unexpected positive finding, as these are not recommended due to the high musculoskeletal strain and prolonged time of reaction to the risk (Tomczak et al. 2012). Only logger 1 adopted such a position for 7.2% of the time during felling.

Incorrect working position is one of the basic factors contributing to musculoskeletal diseases. When the back strongly leans forward it causes strong compression and lateral forces in the lower part of the spine and in the arm and leg joints, which may lead directly to injuries and musculoskeletal disorders (Grzywiński 2010). At the same time, the less natural the posture, the higher the postural strain, i.e. the effort associated with postural stabilization. Consequently, muscle fatigue increases due to disturbed blood flow through the muscles, poorer supply of oxygen and nutrients, and simultaneous intracellular acidification (Makowiec-Dąbrowska 1999).

The European Agency for Safety and Health at Work (EU-OSHA) identifies forestry workers as one of the groups at the highest risk of musculoskeletal disorder (EU-OSHA 2007). The results of the research confirm the negative impact of the working postures of chainsaw-operating loggers on their musculoskeletal system. Further research is needed into possibilities of reducing the postural strain of chainsaw operators by changing operating techniques and organization of work, as well as promoting safe operating postures.

CONCLUSIONS

1. The loggers most frequently adopted postures with their backs leaning forward, both arms below the shoulder joints, and legs straight (2121) or with one leg straight (2131), and with an external load below 10 kg. These postures were adopted during felling, delimbing and bucking.

2. The activities associated with the highest degree of postural strain were delimbing and felling, during which back and leg positions classified as high ergonomic risk postures were predominant.

3. The overall static strain of the loggers was classified as medium. Category III and IV postures (high and very high musculoskeletal strain) were adopted by the loggers for approximately one-third of their working shift.

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