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Workability and Physical Wellbeing Among Chainsaw Operators in Croatia

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Abstract

Motor-manual felling and wood processing is a high-risk work process where the chainsaw, in connection to other variables in the working environment, is a key and constant source of risk and danger for forest chainsaw operators. Pursuant to the foregoing, the purpose of this research is to investigate and compare detected musculoskeletal disorder (MSD) symptoms among the chainsaw workers in Croatia according to their employer (state company – Hrvatske šume Ltd. or private forestry contractor) and self-evaluated Workability Index. A combined three-stage research method was used: (a) defining a sample; (b) preparation and administration of questionnaire; and (c) data analysis and elaboration. The Standardized Nordic Questionnaire (SNQ) was used as a medium to detect musculoskeletal disorder symptoms in chainsaw operators and the Workability Index (WAI) questionnaire was used as a medium for workability self-evaluation. The field part of face-to-face data collection was conducted in the first quarter of 2022 with a total of 158 sampled workers interviewed directly at the forest worksite. Descriptive and inferential statistical methods were used to verify and analyze the data. The anatomical area with the highest 12-month period prevalence of MSD symptoms for all chainsaw operators is the low back (70.89%), followed by the shoulders (41.14%), neck (39.87%) and wrist/hands (36.71%). Research results, according to the employer, showed that workers employed by Hrvatske šume Ltd. have a higher prevalence of MSD symptoms in almost all anatomical locations compared to chainsaw operators employed by private forest contractors. Mean WAI Score among all respondents was 34.96 points (max. 49) falling into the rank »moderate«, while the current workability compared with the lifetime best was 7.33 (range 0–10). The results of MSD symptoms confirm the self-estimated higher values related to health problems caused by forestry work and lower WAI Score by workers employed in the state forestry sector compared to workers employed in private forestry sector. The prevalence of MSD symptoms, observed through WAI Score, showed a significantly lower percentage of affirmative responses for all anatomical regions except for shoulders in workers who need to maintain their workability. The obtained results show positive correlation with descriptive indicators, where younger workers with less chainsaw work experience have a lower prevalence of MSD symptoms and better WAI Score. In the discussion and conclusion part of the research in question, the need for development of possible solutions is emphasized. The proposed solutions can be included into educational programs or on-site training related to the MSD risks for professional chainsaw workers to change their behaviour that will reduce occupational risks.

Keywords: forestry, chainsaw operator, workability, musculoskeletal disorders, Croatia

1. Introduction

Within the forestry industry, injury and mortality rates and types of risk vary based on regional characteristics, job tasks, and wood extraction systems/technologies implemented (Lagerstrom et al. 2019). Works in forestry, especially harvesting operations, according to numerous authors (ILO 1981, Lindroos and Burström 2010, Potočnik and Poje 2017, Landekić et al. 2021) are among the most physically demanding works compared to other economic activities. Work in operational forestry is related to numerous parameters such as high energy consumption, frequent injuries, exposure to vibration, noise, gases, dust and other hazards. In

addition to the high probability that the chainsaw operator will be injured one or more times during his working life, this workplace is additionally risky for the health of workers regarding physically strenuous work with a significant share of ergonomically unfavourable body position (Dimou et al. 2020). In many forestry works, regardless of the certain degree of mechanization, the human body is a basic source of work energy because the motor-manual operation is still heavily represented in the production process. The reason for this situation is the degree of mechanization of production in forestry, which depends largely on factors such as stand type, management method, field and climatic conditions (Vusić et al. 2013)

Today, globally, there are many wood extraction systems which are used every day in forestry, and a large proportion of them still use physical labour in the production process. For example, in Croatia timber extraction is mechanized, while felling and processing are mostly motor-manual and carried out using chainsaws (Mederski et al. 2021); only 3–4% of wood felling is fully mechanized in state forests (Landekić et al. 2021). According to Rony (1975) and Vondra (1995), operators' effectiveness in forest operations, motor-manual or mechanized, is related to numerous parameters such as labour cost, work intensity, age and work experience, motivation and work competencies, work technique and workability, etc. Consequently, operators' wellbeing status researched through musculoskeletal disorders can significantly limit employees' efficiency and, by interaction with other variables in the working environment, constitutes one of the main causes of premature loss of working ability for chainsaw forest workers.

Musculoskeletal disorders (MSD) are the most common occupational health problems - approximately 25% of workers in EU countries (EU-27) complain of back pain and 23% of them suffer from muscle pains. In these countries, 62% of employees are involved in repetitive movements of hands and working tools for at least one quarter of their working time; 46% are subject to painful and irritating positions and 35% are subject to heavy loads or movements (EU-OSHA 2007). It has been established that significant overloads during physical work can result in the appearance of MSD among loggers (Ashby et al. 2001). Numerous scientists (Hagen et al. 1997, 1998, Gallis 2006, Ostensvik et al. 2009, Grzywinski et al. 2016) have investigated the occurrence of MSD symptoms in forestry workers using the Nordic questionnaire. Operators' physical wellbeing is closely connected to working ability, which represents the balance between labour in general and labour resources, where balance means that the individual's workability is sufficient to achieve work goals (Pursio et al. 2021). According to Tengland (2011) and Seeing et al. (2012), working ability determines how the psychosocial, physical and organizational work environment allows employees to use their resources to achieve work goals. Good personal predispositions, such as professional work skills, motivation and good health, increase an individual's resilience and prolong workability as the operating environment and the nature of work change (Tengland 2011, 2013). Some researchers (Landekić et al. 2013, Kymäläinen et al. 2021, Pursio et al. 2021) have previously evaluated the above issue for forestry workers through the workability index questionnaire.

For the Croatian forestry sector, there are no data relating to the prevalence of musculoskeletal disorders and analysis relating to workability index among the chainsaw operators! According to the above, the aim of the paper is to investigate and compare the detected MSD symptoms for chainsaw operators according to the workers' responses and determined workability index.

2. Materials and Methods

In order to analyze the working ability and physical wellbeing among the chainsaw operators in Croatia, a three-stage research method was employed:

⇒ defining a random sample

⇒ preparation and administration of questionnaire

⇒ data analysis and elaboration.

The study area covered the whole of the Republic of Croatia in accordance with the territorial distribution of 17 forest administrations, which are second-layer units within the formal structure of Hrvatske šume Ltd. The company Hrvatske šume Ltd. (CF) manages the state forests and consists of three-layers: headquarters in Zagreb, 17 regional forest administrations (FA) in the second layer (each with 6 to 14 forest offices) and a total of 169 forest offices (FO) in the third layer (Hrvatske šume, 2022). For the purpose of sampling all professional chainsaw operators, a random stratified sample was used for face-to-face survey. Within this sample, a population element was grouped into homogeneous groups or stratums (17 groups consisting of forest administrations i.e. forest offices and an additional three groups consisting of licensed timber harvesting contractors). A sampling of chainsaw operators ($N_{population}$=1237) within the Hrvatske šume Ltd. was conducted within 17 forest administrations and their spatially related forest offices. A sampling of professional forest workers employed by licensed

contractors ($N_{population}$=472) was conducted within three groups (small, medium and large contractors) defined by the Croatian Chamber of Forestry and Wood Technology Engineers according to the type of license they hold and according to the realized annual income for the works in question. The field part of data collection was conducted face-to-face in the first quarter of 2022.

The first step was was to define a random stratified sample step-by-step: each of the 20 defined groups contained the total number of professional forest workers per group or stratum. The proportion for each stratum was calculated based on the total number of workers, and the number of workers to be sampled within each stratum was calculated on the basis of the proportion. The resulting number of sampling workers within each stratum was selected by a simple random sample, where all members of the stratum have an equal chance of being selected, using the »Research Randomizer« calculator (link: https://www.randomizer.org/). Within the stratum, each worker was numbered in alphabetical order by surname (from 1 to *N*) and selected using the above calculator (e.g. within the first stratum, worker number 3, 8, 14, etc.).

The next step was to develop and test the questionnaire with the aim of assessing workability according to Tuomi et al. (1998) and physical wellbeing or in this case musculoskeletal disorders according to Kuorinka et al. (1987). The questionnaire contained 3 parts:

- ⇒ a general section on the respondent and the working tool (chainsaw)
- ⇒ assessment of the Workability Index (7 standardized questions)
- ⇒ standardized Nordic questionnaire (27 short questions versus nine body parts).

2.1 Standardized Nordic Questionnaire

Through the history, different methods have been developed for evaluating the frequency of musculoskeletal disorders symptoms (MSD) in each of the subdisciplines like ergonomy or work safety. Such methods mentioned above usually detect the location of the problem, but they do not quantify it numerically or isolate it with precision. For the purposes of detecting musculoskeletal disorders in this research, as indirect method, a Standardized Nordic Questionnaire was used. Kuorinka and his team (1987) developed the Nordic Musculoskeletal Questionnaire (NMQ) with the support of the Nordic Council of Ministers.

This simple questionnaire detects symptoms in the neck, back, shoulders, and extremities (De Barros and Alexandre 2003). The questionnaire has 27 questions structured in three well-differentiated parts. The first general part applies to symptoms detection (yes/no answer) in 9 parts of the body (neck, shoulders, elbows, wrists/hands, upper back, lower back, hip/thighs, knees, and ankles/feet) during the last 12 months. The second part refers to inability to perform daily work activities due to the appearance of detected symptoms in body parts during the last 12 months. The third part refers to symptoms (yes/no) in 9 parts of the body during the last 7 days.

According to López-Aragón et al. (2017), the basic advantages of the questionnaire are standardization of the questions, worldwide recognition, possibility of self-evaluation, relatively quick identification of the symptoms and applicability in large populations. Regarding the adaptation and validation of the questionnaire, the above has been carried out in some European countries like Greece (Antonopoulou et al. 2004), Italy (Gobba 2008), Poland (Zejda 2009), France (Legault et al. 2014) with more or less satisfactory results.

2.2 Workability Index

The Finnish Institute of Occupational Health developed Workability Index (WAI) questionnaire (Ilmarinen 1991, Tuomi 1997) for evaluating one's workability. The questionnaire was basically developed for scientific purposes, but according to Ilmarinen (2007), the methodology in question quickly spread to other countries, both as part of practice (like medicine) and as part of scientific work and is by far the most used and accepted tool for measuring workability (Van der Berg et al. 2009).

As a tool, it is applicable in the occupational safety system where it indicates how well a worker can perform his daily tasks. By giving answers through seven questions, which are related to the physical and mental requirements of the job, the worker achieves a result in values between 7 and 49 points, which numerically illustrate working and functional ability of each participant. Indicators and scale range for the measurement of Workability Index can be found in research by Ilmarinen (2007) or Landekić et al. (2013).

Implementation of necessary measures aimed at restoring workability or additional evaluations of workability are needed by those whose workability is graded poor (maximum score 27). For those whose workability is moderate (score 28–36), measures to help improve workability are recommended. Workers with a good workability index (score 37–43) should receive instructions on how to maintain their workability. Those whose workability is excellent (44–49) should also be informed about which work and lifestyle factors maintain work ability and which factors weaken it (Tuomi et al 1998).

2.3 Statistical Analysis of Data

The Microsoft Excel® software was used in the first step for data entry, data systematization and primary processing. Further data analysis was performed using statistical software: Statistics 14® (Dell Software, Round Rock, Texas, United States) and SPSS 28® (IBM, Armonk, New York, United States). A statistical significance was based upon $p<0.05$.

Age of respondents was divided into four groups (group 1 = less than 29 years; group 2 = from 30 to 39 years; group 3 = from 40 to 49 years, group 4 = more than 50 years). The years of total work experience were divided into four groups (group 1 = less than 9 years; group 2 = from 10 to 19 years; group 3 = from 20 to 29 years, group 4 = more than 30 years). The chainsaw work experience in the logging industry was divided into three groups (group 1 = less than 5 years; group 2 = from 6 to 15 years; group 3 = more than 16 years).

Two continuous variables, MSD Score and WAI Score, were created for each respondent by summing the number of anatomical areas with a reported MSD or points given for a specific indicator of workability. Also, MSD K-Score was created for each respondent based on the positive answers obtained in the second part (yes/no for inability to perform daily work) and the third part (yes/no for symptoms during the last 7 days) of the NMQ. Continuous variable for musculoskeletal disorders symptoms with a coefficient of increase, i.e. MSD K-Score, was calculated based on the percentage of positive responses in the second and third part of the NMQ, and in relation to the sampled population of workers. Positive responses by body parts in the first part of the questionnaire (i.e. MSD Score) were multiplied by a coefficient of 1.34 (share of responses yes less than 34%) if the answer was affirmative in the second and third part of the NMQ. The purpose of the MSD K-Score is related to highlighting the answers from second and third part of the

Table 1 General information about sampled chainsaw operators

Profile of interviewees		Hrvatske šume Ltd.		Private forest company	
		111 (70.30%)		47 (29.70%)	
		n	%	*n*	%
Gender	Male	111	70.30	47	29.70
Age groups	≤29	29	26.13	6	12.77
	30–39	42	37.84	16	34.04
	40–49	29	26.13	16	34.04
	≥50	11	9.90	9	19.15
Chainsaw work experience groups	≤5	49	44.14	24	51.06
	6–15	38	34.24	19	40.43
	≥16	24	21.62	4	8.51
Level of education	Primary school or lower	26	23.42	21	44.68
	High school or higher	85	76.58	26	55.32
Minor injuries at work	No injuries	54	48.65	25	53.20
	Once	30	27.03	15	31.91
	Twice	19	17.12	4	8.51
	Three or more times	8	7.20	3	6.38
Severe injuries at work	No injuries	88	79.28	41	87.23
	Once	16	14.41	6	12.77
	Twice	4	3.61	0	0.00
	Three or more times	3	2.70	0	0.00
Working days per week	Five days	111	100.00	25	53.19
	Six days	0	0.00	22	46.81
Working hours per day	Eight hours	111	100.00	37	78.72
	Nine or more hours	0	0.00	10	21.28

Standardized Nordic Questionnaire through the calculation of the cumulative impact of MSD symptoms affecting the workability of the subjects (inability to perform daily work activities). One binary variable was created based on the results of the WAI Score to identify workers who need to restore or improve workability (36 or less points) and workers who need to receive instructions on how to maintain their workability (37 or more points)!

Descriptive statistical analysis was applied to calculate means, standard deviations, and frequency statistics for all demographic variables. For each variable, an appropriate test of distribution normality and homogeneity of variance was made (Shapiro-Wilk's and Levine's test) on the basis of which the following data processing were performed.

T-tests or alternative nonparametric Mann-Whitney *U* test were performed to determine if chainsaw operators employed by Hrvatske šume Ltd. versus workers employed by licensed private contractors were statistically similar in terms of age, total and chainsaw work experience, hours worked per day and week, WAI Score, MSD Score and MSD K-Score. Chi-square (χ^2) tests were performed to determine if there is a significant difference in the prevalence of MSD symptoms in each anatomical region based on binary WAI Score variable.

For analysis of variance, One-way ANOVA or alternative nonparametric Kruskal-Wallis test was used to test the differences between the defined groups of age, work experience total and chainsaw work experience versus the WAI Score, MSD Score and MSD K-Score. Two-way ANOVA was used to test the differences between the defined groups of chainsaw work experience and type of employer versus the WAI Score.

3. Results

The survey of chainsaw operators was conducted face-to-face directly at the forest sites during the first quarter of 2022. From the total number of sampled workers (n=158), 29.70% were employed by a private contractor in forestry, and 70.30% by the company Hrvatske šume Ltd. (Table 1), which manages the state forests in the Republic of Croatia. Table 1 shows general data on the conducted survey and the profile of the respondents. The age distribution and work experience of the chainsaw operators involved versus employer corresponded well to the age distribution of the general population.

Since the Shapiro-Wilk test proved that age variable in database follows normal distribution (p-value of 0.19), *T*-test was used to test the difference of age variable versus the type of employer. The differences for age variable were found to be statistically significant between chainsaw operators employed in Hrvatske šume Ltd. (M=36.79; SD=8.80) and chainsaw operators employed by private forestry contractors (M=40.57; SD=10.14) with $t(156)$=2.359, p=0.020 (Table 1). Other variables used for further analyses do not follow normal distribution (p-value less than 0.05). Based on the above, non-parametric Chi-square test or Mann-Whitney *U* test was used in further data analysis. Chi-square independence test (with continuity correction) showed a small to moderately significant relationship between the employer and the level of education χ^2 (1, 158)=6.16; p=0.01; fi=0.21 (Table 1). The Mann-Whitney *U* test was used to analyze and compare working days per week and working hours per day versus type of employer. The Mann-Whitney *U* test revealed a statistically significant difference for the number of working days per week among chainsaw operators employed in Hrvatske šume Ltd. and chainsaw operators employed by private forestry contractors U=1387.50, z=-7.745, p=0.00 (Table 1). Using the same test, a statistically significant difference was also found for the working hours per day among chainsaw operators employed in Hrvatske šume Ltd. and chainsaw operators employed by private forestry contractors U=2053.50, z=-5.004, p=0.00 (Table 1).

In the first part of the questionnaire, the respondents were asked to rate their own feeling of health difficulties due to work in forestry with grades from 1 (no health difficulties) to 10 (significant health difficulties). Using the Mann-Whitney *U* test, a statistically significant difference was found for rated health difficulties among chainsaw operators employed in Hrvatske šume Ltd. (Md=3.0, n=111) and chainsaw operators employed by private forestry contractors (Md=2.0, n=47) U=1387.50, z=-7.745, p=0.00 (Table 1).

Table 2 demonstrates the percentages of MSD symptoms reported by chainsaw operators employed in Croatia forestry sector. The anatomical area with the highest 12-month period prevalence of MSD symptoms for all chainsaw operators (Table 2) was low back (70.89%), followed by the shoulders (41.14%), neck (39.87%) and wrist/hands (36.71%). The lowest 12-month period prevalence of MSD symptoms for all chainsaw operators (Table 2) was hips/thighs and elbows. The chainsaw operators employed by Hrvatske šume Ltd. had a higher prevalence of MSD symptoms in almost all anatomical locations compared to chainsaw operators employed by private forest contractor (Table 2). Statistically significant differences regarding the type of employer was not found between anatomical

Table 2 Percentage of chainsaw operators reporting musculoskeletal symptoms (one-year period prevalence)

Anatomical location of MSD symptoms	All responses (n=158)	Hrvatske šume Ltd. (n=111)	Private forest company (n=47)
Neck	39.87%	48.65%	19.15%
Shoulders	41.14%	45.05%	31.91%
Elbows	17.09%	19.82%	10.64%
Wrist/Hands	36.71%	40.54%	27.66%
Upper Back	29.75%	33.33%	21.28%
Lower Back	70.89%	73.87%	63.83%
Hip/Thighs	15.82%	13.51%	21.28%
Knees	32.91%	31.53%	36.17%
Feet	28.48%	31.53%	21.28%
Missed work due to symptoms in any area	14.98%	18.92%	5.67%
MSD Score (Mean number)	3.13	3.37	2.55
MSD K-Score (Mean number)	4.05	4.47	3.07

locations except for the neck area χ^2 (1, 158)=6.54; p=0.01; fi=0.22.

No significant differences were found in the MSD Score between chainsaw operators employed by Hrvatske šume Ltd. and chainsaw operators employed by private forest contractor. On the other hand, significant differences were found in the MSD K-Score between chainsaw operators employed by Hrvatske šume Ltd. (*Md*=3.68, *n*=111) and chainsaw operators employed by private forest contractor (*Md*=2.68, *n*=47) *U*=2043.50, *z*=-2.157, *p*=0.03.

For workability assessment of the sampled chainsaw operators, the focus is to numerically display their physical wellbeing and job readiness in relation to the requirements of their current workplace. Mean workability index among all sampled chainsaw operators in Croatia forestry sector was 34.96 points falling into the rank »moderate«. Analyzed according to the share of each group, 7.00% of respondents reached the rank »excellent«, 36.7% »good«, 42.40% »moderate« and 13.90% »poor«. Mean score of chainsaw operators' workability index, employed in Hrvatske šume Ltd. and in private companies, is shown in Table 3. Results of workability average score show a negligible difference between the chainsaw operators employed in the private and state forestry sector, with a »moderate« job ability (necessary measures for improvement of workability are needed).

Table 3 Descriptive values for indicator of workability – Hrvatske šume Ltd. versus private contractors

WAI indicators		Hrvatske šume Ltd.				Private forest company			
		M	*SD*	*Min.*	*Max.*	*M*	*SD*	*Min.*	*Max.*
Q1	Comparison of WA with lifetime best	7.19	1.97	4	10	7.66	1.49	4	10
Q2	WA in relation to job demands	6.60	2.18	2	10	7.32	2.08	3	10
Q3	Number of current diseases	5.53	1.14	0	6	5.36	1.03	1	6
Q4	Interference of health problems	4.77	1.42	1	6	4.83	1.48	1	6
Q5	Sick leave during past year	3.42	1.37	1	5	4.02	1.26	1	5
Q6	Own prognosis of WA	4.01	1.64	1	7	4.57	1.35	3	7
Q7	Mental resources	2.63	1.05	1	4	3.09	0.88	1	4
WAI Score		34.16	6.53	13	45	36.85	5.57	20	44

Numerically obtained value of workability for chainsaw operators, regarding descriptive and measured variables presented in Table 4, was compared through binary WAI variable (group 1: restore or improve their workability (n=89); group 2: maintain their workability (n=69)). Using the Mann-Whitney U test, a statistically significant difference was found for descriptive variables (age, total and chainsaw work experience, minor and severe injuries) among chainsaw operators who need to restore or improve their workability and chainsaw operators who need to maintain their workability (Table 4). For chainsaw operators who need to restore or improve their workability: the mean value for age is 40.48, the mean value for total work experience is 16.35, the mean value for chainsaw work experience is 11.67, the number of minor injuries at work is 0.94 per sampled worker and the number of severe injuries at work is 0.40 per sampled worker. On the other hand, for chainsaw operators who need to maintain their workability: the mean value for age is 34.61, the mean value for total work experience is 11.99, the mean value for chainsaw work experience is 5.44, the number of minor injuries at work is 0.68 per sampled worker and the number of severe injuries at work is 0.09 per sampled worker. Statistically significant difference was also found for MSD Score and MSD K-Score variable between chainsaw operators compared through binary WAI variable (Table 4). The average MSD Score per sampled worker who needs to restore or improve his workability is 3.98 and 2.03 for worker who needs to maintain his workability. The average MSD K-Score per sampled worker who needs to restore or improve his workability is 5.30, and 2.45 for worker who needs to maintain his workability.

Chi-square (χ^2) tests were performed to determine if there is a significant difference in the prevalence of MSD symptoms in each anatomical region based on binary WAI Score variable (Table 5). All anatomical regions except for shoulders resulted in a statistically significant difference between the chainsaw operators who need to restore or improve their workability and chainsaw operators who need to maintain their workability (Table 5). Phi coefficient showed a small to moderately significant relationship, except for elbows, between the binary WAI groups and the prevalence of MSD symptoms in chainsaw operators (Table 5).

Table 4 Mann-Whitney U test results for binary WAI variable

Variable	*U*-value	*Z*-value	*p*-value
Age	2007.50	-3.729	0.00
Work experience total	2249.50	-2.882	0.00
Chainsaw work experience	1792.00	-4.207	0.00
Minor injuries at work	2455.00	-2.342	0,02
Severe injuries at work	2398.00	-3.503	0.00
Feeling of health difficulties	1711.00	-4.843	0.00
MSD Score	1661.50	-4.984	0.00
MSD K-Score	1608.50	-5.145	0.00

Table 5 Prevalence of MSD symptoms in each anatomical region based on binary WAI variable

Variable	X^2	*p*-value	Phi coefficient
Neck	10.759	0.00	-0.274
Elbows	5.084	0.02	-0.196
Wrist/Hands	18.226	0.00	-0.353
Upper Back	6.076	0.01	-0.210
Lower Back	6.848	0.01	-0.222
Hip/Thighs	5.670	0.02	-0.207
Knees	6.056	0.01	-0.209
Feet	8.394	0.00	-0.245

Testing of differences, within the respondents' database, was carried out between the WAI Score and selected descriptive variables (four age groups, four groups for work experience total and three groups for chainsaw work experience). Since Shapiro-Wilk test proved that WAI Score in the database did not follow normal distribution (p-value of 0.00), and Levine's test rejected the assumption of homogeneity of variance, Kruskal-Wallis test was used for further analysis. Testing the WAI Score values among defined groups of respondents resulted in the following statistically significant differences (Table 6).

By using the Mann-Whitney U post-hoc test, it was determined that the mean WAI Score value in group 4 (more than 50 years of age) (M=31.60; N=20) is significantly different from age group 1 (less than 29 years)

Table 6 Testing the difference between WAI groups using Kruskal-Wallis H test

Variable	X^2	*df*	*p*-value
Age	15.264	3	0.00
Work experience total	8.945	3	0.03
Chainsaw work experience	26.724	2	0.00

(*M*=36.16; *N*=35) and age group 2 (from 30 to 39 years) (*M*=36.50; *N*=58). A statistically significant difference was not determined between other age groups. For the groups regarding work experience total, by using post-hoc *U* test, it was determined that the mean WAI Score value in group 2 (from 10 to 19 years) (*M*=36.40; *N*=67) is significantly different from group 3 (from 20 to 29 years) (*M*=32.02; *N*=28) and group 4 (more than 30 years) (*M*=31.09; *N*=11). Regarding groups for chainsaw work experience, by using post-hoc *U* test, it was determined that the mean WAI Score value in group 3 (more than 16 years) (*M*=29.79; *N*=28) is significantly different from group 1 (less than 5 years) (*M*=36.99; *N*=73) and group 2 (from 6 to 15 years) (*M*=34.91; *N*=57).

Two-way ANOVA was used to test the differences between defined groups of chainsaw work experience and type of employer according to the WAI Score (Fig. 1). Figure one shows that, regardless of the employer, the WAI Score decreases with the increase of chainsaw work experience. Although there is no evidence of a statistically significant difference between WAI scores in the two sampled employers in terms of years of chainsaw work experience (Fig. 1), workers with more than 16 years of chainsaw work experience in the state sector (Hrvatske šume Ltd.) show a better workability and physical wellbeing in relation to the operators working in the private forestry sector.

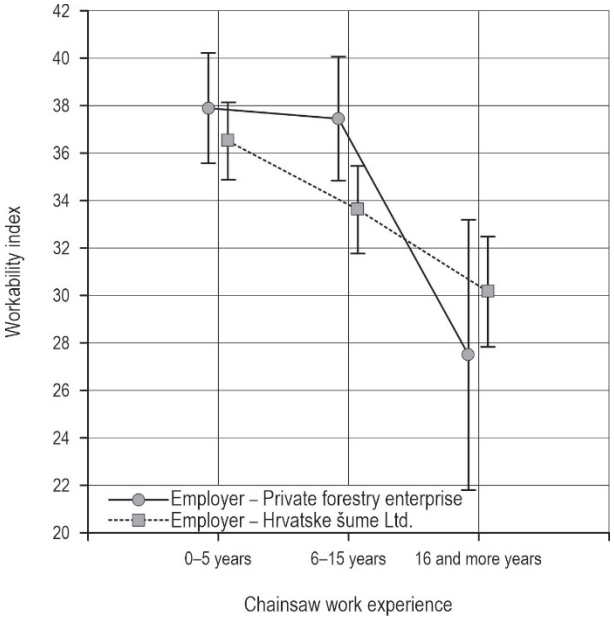

Fig. 1 WAI Score of chainsaw operators in private and public forestry sector versus groups of chainsaw work experience

4. Discussion and Conclusions

Despite the applied methods of felling and wood processing in developed countries, where mechanized felling is widely practiced, in the forestry of the Republic of Croatia there is still a significant share of motor-manual felling and wood processing (approximately 96.00% of annual cut in Hrvatske šume Ltd.). Work related to wood harvesting, especially motor-manual felling and wood processing, is a high-risk work process where the chainsaw is a key and constant source of risk and danger for physical wellbeing of forest workers. The main risk factors identified and studied in connection with the use of a chainsaw are related to experience (Wang et al. 2003, Lefort et al. 2003), seasonality of work and type of enterprise (Picchio et al. 2010, Montorselli et al. 2010), frequency of chainsaw use (Albizu-Urionabarrenetxea 2013, Lilley et al. 2002), etc. Consequently, the study was designed with the purpose of determining overall physical wellbeing among the chainsaw operators in Croatian forestry sector through the prevalence of musculoskeletal disorder symptoms and workability score value.

In the presented research and analysis, certain limitations should be considered when interpreting the results. The basic shortcoming of the research is the fact that the sample of chainsaw operators from private forestry companies was too small (the random stratified sample resulted in 57 workers needed to be sampled, and in this research it was 47 respondents), which excludes the adoption of strong general conclusions. The argument for generalizing research results is supported by a geographically even relative distribution of respondents throughout the Croatian forestry sector, especially for private forest companies regarding different sizes, company types, regionality, etc. Another shortcoming is that this research included only currently employed workers at operations of felling and wood processing, and did not take into account labour turnover between activities; workers may have changed jobs due to the lack of labour force in a particular occupation, better working conditions, better wages, etc.

Regarding the aspect of descriptive indicators of sampled workers and based on the measured and expected frequency, and the conducted Hi-square test, it can be concluded that chainsaw operators employed in the company Hrvatske šume d.o.o. have significantly higher level of education than chainsaw operators employed by private contractors in forestry. In the research by Landekić et al. (2013) of forestry machine operators, it was concluded that workers from private sector have insignificantly higher education level than

the operators employed in Hrvatske šume Ltd. In the current capitalist economy, the forestry industry is associated with an increased productivity pressure and excessive shift lengths in mechanized felling (Nieuwenhuis 2002), but also in motor-manual felling and wood processing (Dimou et al. 2020). The implementation of the non-parametric *U* test confirmed the well-known fact in the Croatian forestry sector that chainsaw operators employed by private forestry contractor work more days and hours within a working week compared to workers employed in Hrvatske šume Ltd. (a company that manages state forests).

In this study, the physical wellbeing among the chainsaw operators was addressed from the perspective of the prevalence of musculoskeletal disorder symptoms and workability score value. Certain studies have highlighted the relationship between musculoskeletal symptoms prevalence and age (Malchair et al. 2001, Naidoo et al. 2009, Heiden et al. 2013), where tension usually increases as age and work experience increase, and therefore the percentage of individuals with musculoskeletal symptoms is higher in older workers (De Zwart et al. 1997, Nordin et al. 2007). In the current study, the prevalence of MSD symptoms in any part of the body were nonsignificant between the employer, but the chainsaw operators employed by Hrvatske šume Ltd. had a higher prevalence of MSD symptoms in almost all anatomical locations compared to chainsaw operators employed by private forest contractor (Table 2). The reason for the above can be related to the high fluctuation of workers employed by a private contractor at the workplace in question, and, within the same age group, to a lesser number of years of felling and processing of wood compared to chainsaw operators employed in the company HŠ Ltd. For the total number of participants, the mean prevalence of MSD symptoms was 70.89% in the low back, followed by 41.14% in the shoulders, 39.87% in the neck and 36.71% in the wrist/hands. Compared to similar studies by Hagen et al. (1998), who focused on Norwegian workers employed in motor-manual harvesting (24.8%% in the low back), and Lagerstrom et al. (2019), who focused on forestry employees in Montana (38% in the lower back, 28% in the shoulders and 25% in the knee and neck), the prevalence of disorders in the current study was found to be higher. Compared with the results of the present study, only the prevalence in the lower back area was higher than in the study by Dimou et al. (2020), who focused on chainsaw works in central Greece, and in the study by Grzywiński et al. (2016), who focused on loggers employed in Poland. The average mean value of MSD Score between type of employer did not show significant differences.

When evaluating the current workability compared to the lifetime best, a somewhat lower mean (7.19 at Hrvatske šume Ltd. and 7.66 at private forestry companies) was obtained in the present study than in studies by Rytkönen et al. (2008) or Kymäläinen et al. (2021).

When comparing the mean WAI Score of the present study (34.96) to other occupational groups internationally (Landekić et al. 2013, Kymäläinen et al. 2021), chainsaw operators in Croatia have a higher average WAI Score. The difference obtained in the WAI Score is closely related to the working risk and physical complexity of the job at the workplace of chainsaw operators, and in relation to the workplace of forest machine operator. When comparing the same indicator according to the type of employer, a slightly higher WAI Score was recorded for chainsaw operators employed by Hrvatske šume Ltd. When asked about their own feeling about health problems due to work in forestry, the workers employed by Hrvatske šume Ltd. pointed out the greater importance of these problems, i.e. they gave a higher average score that is statistically significantly different from the score given by workers employed by a private contractor in forestry, which supported the difference between the mean value of WAI Score.

The testing of descriptive indicators for sampled workers versus binary WAI Score variable showed that the chainsaw operators who need to maintain their workability (WAI Score 37 or more points) have statistically lower mean values regarding age, work experience total, chainsaw work experience and the frequency of severe and minor injuries in relation to workers who need to restore or improve their workability. For the prevalence of MSD symptoms in each anatomical region based upon binary WAI Score variable the difference with a statistically significantly lower percentage of affirmative responses for all anatomical regions except for shoulders was obtained in workers who need to maintain their workability (Table 5). The obtained result is correlated with descriptive indicators where younger workers with less chainsaw work experience have a lower prevalence of MSD symptoms and better WAI Score.

Analysis of the WAI Score against defined groups for descriptive variables (age, total work experience, chainsaw work experience) showed that the mean values of the indicators differ significantly between younger workers with less chainsaw work experience (up to 5 years) compared to older workers with chainsaw work experience over 16 years (Table 6). Although Fig. 1 shows no evidence of a statistically significant difference compared to workers employed in Hrvatske šume Ltd., the WAI Score is falling significantly and

sharply among workers who are employed by a private forestry contractor and have 16 or more years of chainsaw work experience in forestry.

According to study results and the set research objectives, regarding workability and physical wellbeing of the chainsaw operators in Croatia, the following conclusions are drawn:

- ⇒ wellbeing of the chainsaw operators, observed through prevalence of MSD symptoms, is in the middle of the results reported by other studies, except for the low back area where the highest percentage was recorded
- ⇒ workability of all sampled chainsaw operators, observed through WAI Score, is below average as compared to some other occupational groups
- ⇒ the prevalence of MSD symptoms, observed through WAI Score, showed a significantly lower percentage of affirmative responses for all anatomical regions except for shoulders in workers who need to maintain their workability (WAI Score 37 or more points)
- ⇒ regarding the type of employer, workability of the chainsaw operators employed in private forestry sector, compared to state sector, is slightly higher and declines during the increase in chainsaw work experience, especially after 16 years of motor-manual work
- ⇒ as the previous workers' activities (workloads) were not recorded, this research and its results also point out the need for continuous monitoring and regular periodic assessment of forestry workers' workability/workload
- ⇒ the solutions for supporting and maintaining workability and physical wellbeing of chainsaw operators need to be developed through further research and included into periodical training.

One possible solution according to Lagerstrom et al. (2019) is to develop educational programs related to the MSD risks for professional chainsaw operators and to integrate safety culture into their annual safety training. Another solution according to Çalişkan (2018) and Kymäläinen et al. (2021) is to arrange in-service training of the forest workers on issues such as work, working position, working conditions, lifestyle and habits in order to change their behaviour and thus reduce occupational risks.

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