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Effect of the body mass index and length of work on the stress of individual body parts of chainsaw operators

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Abstract: The subject of this study is to point out the issue of various impacts of musculoskeletal disorders in chainsaw operators and their impact on human health. The first goal was to find out whether the body mass index is responsible for excessive stress to individual parts of the body of chainsaw operators at work. The second goal was to determine whether the excessive load to the individual body parts is affected by the time of working with the chainsaw. Questionnaires created for the fulfilment of the goals were distributed to professional forest loggers working in the Czech Republic, which were filled in by 161 of them. Questions in the first part of the questionnaire were formulated in such a way that answers to them would clearly identify information on the individual respondents. The second part of the questionnaire was focused on the assessment of the load upon 12 body parts of the operators (each part being split into the right and left sides). The results of the statistical analysis showed that neither the body mass index (*BMI*) nor the length of time working with the chainsaw affect the load on the individual parts of the body of the chainsaw operators.

Keywords: ergonomics; forestry; musculoskeletal disorders (MSD); tree felling; workload

Work in the forest, and timber logging in particular, features specific characteristics (Melemez 2015) and is traditionally considered one of the most difficult and highly dangerous industries to work in (Gallis 2006; Gejdoš et al. 2019). There are many factors why it is considered difficult, e.g. the necessity of everyday work, handling heavy objects, working in steep and uneven terrain, working in permanently changing climatic conditions or high energy consumption (Gümüş, Türk 2012).

The work of chainsaw operators includes three main manual tasks: felling, delimbing and bucking (cross-cutting). The main biomechanical risk factors to which the chainsaw operators are exposed are vibrations of the hands and arms (Staněk et al. 2023b), uncomfortable body postures, lifting of heavy objects, long-term inappropriate body positions, repeated movements (Dimou et al. 2020; Iftime et al. 2020) and a lack of breaks, which may cause musculoskeletal disorders (MSD; EU-OSHA 2018). It is well known that not observing breaks and, hence, the great load with manual work is closely related to the occurrence of MSD in chainsaw operators (Ashby et al. 2001). There are also many combined factors which can cause musculoskeletal symptoms. These symptoms can be affected by work techniques, work organi-

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sation and individual characteristics. Psychosocial factors can play a certain role, too (Gallis 2006). The increased prevalence of MSD in loggers complaining of fatigue of lower limbs may be related to carrying heavy equipment or to walking across steep and diverse terrains (Axelsson 1998).

Work positions represent a relatively well-explored factor, but postural aspects in the human-machine interaction have not been sufficiently investigated so far (Potočnik, Poje 2017). Roles played by the work postures, loads and techniques in the development of MSD among chainsaw operators are very important. For example, using a chainsaw during felling on steep terrain in an inappropriate and uncomfortable position, together with supporting its heavy weight, represents an increased load on the musculoskeletal system. During all operations, the hands and wrists are supported, held and directed under the steady load of a running chainsaw (Gallis 2006).

Uncomfortable working postures can impair the concentration of workers and increase the frequency of accidents as well as increase biomechanical overload (Lee et al. 2011; Caffaro et al. 2018). This may lead to MSD in various parts of the body, e.g. at the level of the joints and vertebra (Devereux, Buckle 2007).

Basic work characteristics of chainsaw operators during felling and processing the trees include, for example, starting the chainsaw, performing undercuts, final cuts, etc.; these operations require the operator to hold the saw constantly in front of the body. The highest risk for chainsaw operators is felling and delimbing where the working position, together with the duration, can be classified as highly risky from an ergonomic point of view (Röjgren, Widell 2022). The warning indicator is that the operator's body position when bending is greater than 60°. It would be, therefore, useful to mention this information which could lead to a reduction in inappropriate working positions in the process (Masci et al. 2022) of health and safety training. It is also recommended that the forearm and hand are in a semi-supinated position during the starting of the chainsaw (Srinivasan 2022). To reduce the risk of musculoskeletal system disorders, chainsaw operators should be informed about the correct position of the upper body, according to the hip hinge rule (Srinivasan 2022).

As compared with workers in other industries, forest workers are particularly endangered by MSD due to the characteristics of the work tasks and conditions in which their activities are carried out (Masci et al. 2020). A high prevalence of MSD observed in forest workers (Gallis 2006; Grzywinski et al. 2016) highlights the need for ergonomic research in forest operations as a necessity rather than a factor of improved safety and well-being for forest workers (Tsioras et al. 2022). Questionnaires for MSD analyses have been used in several research works (Newell, Kumar 2004; Glover et al. 2005; Lei et al. 2005), which have garnered a great deal of attention of experts and are frequently cited. Providing useful and reliable information, standardised questionnaires appear to be the most obvious means and method of data collection, estimation, recording and analysis of MSD (Gallis 2006).

The above-mentioned reasons resulted in this research which deals with two issues: whether the body mass index (*BMI*) causes excessive stress to individual body parts of chainsaw operators at work and whether the excessive stress to individual body parts of chainsaw operators is affected by the time of chainsaw use. The aim of this study is to draw attention to the issue of MSD in forest loggers and its impact on their health.

MATERIAL AND METHODS

Data acquisition. A questionnaire that aimed at obtaining the necessary information from forest loggers and whose content was focused on the local musculoskeletal system of individual human body parts was presented to chainsaw operators in an electronic form (online). The data collection started on February 13, 2023, and ended on March 21, 2023. Participation in the questionnaire survey was voluntary and anonymous (personal data were not required from the respondents, and none of the respondents knew how the other respondents answered the questions). The respondents were free to end the questionnaire at any time and were provided no remuneration for filling it in. The questionnaire was created in Google Forms software. Before starting to fill in the questionnaire, the respondents were informed about its anonymous character, content and the purpose of the data collection. They also agreed that the data from the questionnaire would be used for research purposes and published in a professional journal. All the respondents agreed with the data disclosure from the questionnaire.

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The questionnaire consisted of two parts. The first part contained questions focusing on the personal data of the respondents providing their general profile. The answers to these questions were used by the authors of this paper in processing and evaluating the data from the second part of the questionnaire. The questions in the first part of the questionnaire were as follows: (1) Sex (male/female); (2) Age (16–20, 21–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56 and older); (3) Dominant hand (right/left); (4) Height (cm); (5) Weight (kg); (6) How many years have you been working as a logger?; (7) Approximately how many hours per week do you work with the chainsaw?; (8) What chainsaw type do you use (designation)?; (9) At which side of your body do you hold the chainsaw when felling a tree?; (10) Do you suffer from any health complications/illnesses which could impair your performance as a chainsaw operator? If so, what kind?; (11) Have you suffered any occupational injuries relating to the chainsaw operation? If so, what kind?; (12) Do you consider yourself a 'physically active person'? Do you do sports or exercise? If so, approximately how many hours a week?

The second part of the questionnaire contained questions already focusing on the individual body parts of the chainsaw operators and the magnitude of the fatigue. Using a scheme (that was part of the questionnaire – Figure 1), the respondents were to specify the degree (magnitude) of fatigue in their body parts. The degree of fatigue was classified based on a scale from which the respondents chose one answer for the specific part of the body: 0 – none at all; 1 – mild; 2 – average; 3 – heavy; 4 – excessive.

The number of chainsaw operators (males) working in the Czech Republic who responded to the online questionnaire and, hence, to the data collection was 161. All of them were professional forest loggers.

In order to verify the aim of the research and whether the magnitude of the *BMI* caused excessive stress to the individual body parts of chainsaw operators, the authors of this research worked with the body weight and height of the chainsaw operators. The *BMI* was determined from the following Equation (1):

$$BMI = \frac{weight\ of\ the\ individual\ (\text{kg})}{[height\ of\ the\ individual\ (\text{m})]^2} \quad (1)$$

The calculated result was then allocated to the individual chainsaw operators and compared with the 'nutritional status' defined by the World Health Organization (WHO; Table 1), then it was subjected to a statistical analysis.

The second goal of the research, i.e. whether excessive stress to the individual body parts of the loggers is caused by the time spent using the chainsaw, was assessed by means of a statistical analysis. The time spent using the chainsaw is understood to be the number of hours working with the chainsaw per week and the length of the operators' practical experience.

Data analysis. The data from the questionnaire were transferred into Microsoft Excel where

Key	Body part	Right	Left
1	Neck		
2	Shoulders		
3	Upper part of the back		
4	Lumbar part of the back		
5	Arms		
6	Elbows		
7	Forearms		
8	Wrists and hands		
9	Hips		
10	Knees		
11	Lower legs_		
12	Legs		

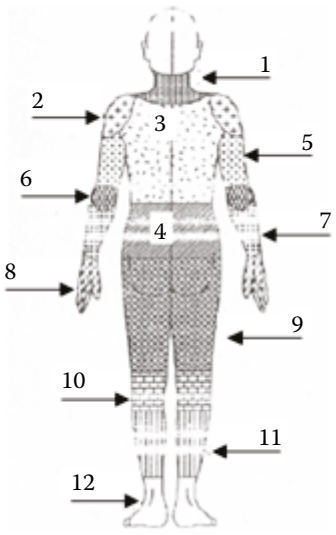

Figure 1. Scheme for the assessment of muscle load (Hlávková, Valečková 2007)

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Table 1. Nutritional status

Body mass index (*BMI*)	Nutritional status
Below 18.5	underweight
18.5–24.9	normal weight
25.0–29.9	pre-obesity
30.0–34.9	obesity class I
35.0–39.9	obesity class II
Above 40.0	obesity class III

Source: WHO 2010

they were divided into groups according to the individual parts of the body. Each respondent was allocated a serial number according to the date when he sent the filled questionnaire. This means that the first respondent who sent the questionnaire was allocated serial number 1 and the last respondent who sent the questionnaire was allocated serial number 161.

In order to find out whether the *BMI* causes excessive stress to the individual body parts of the chainsaw operators at work and whether the excessive stress is affected by the time of using the chainsaw, a correlation was used whose result was applied in the test of the correlation coefficient significance (*R*). To demonstrate the mentioned correlation, the test criterion (the result of the test) had to be higher than the critical value, which equals the quantile of the Student's distribution at a probability of 0.05. The value of the degree of freedom for the calculation of Student's quantile was 3. Then, descriptive statistics were performed for the recorded data to provide a better representation.

RESULTS

In our research, all the age groups of the chainsaw operators were studied; altogether 161 persons (all males) responded. Of them, 7.45% were aged 16–20 years, 22.98% were aged 21–25 years and 20.50% were aged 26–30 years (Figure 2). The group of operators aged 31–35 years occupied 10.56% and the group of operators aged 36–40 years included 0.62% more respondents (11.18%). Even more persons were represented in the age group of 41–45 years (12.42%). The group of operators aged 46–50 years was considerably smaller (7.45%). Persons 51 years and older participated at 7.45%; of them, 2.48% were aged 51–55 years, and the remaining 4.97% were aged 56 years and older (Figure 2).

Table 2 shows the data about the height of the chainsaw operators. The greatest reported height was 205.00 cm, which is 23.4224 cm more than the average height (181.5776 cm). The shortest person's height was 12.5776 cm less than the average height. The minimum height was 169.00 cm. The most frequently occurring height of the respondents was 178.00 cm. As to the weight, the heaviest reported value was 145.00 kg, which was 53.1863 kg more than the average weight (91.8137 kg). The minimum weight was 31.8137 kg lower than the average weight. The lowest weight of the respondent was only 60.00 kg. The most frequently reported weight was 100.00 kg. Looking closer at Table 2, the value of the standard deviation (17.750070) can be noted, which shows that the weight of chainsaw operators was consid-

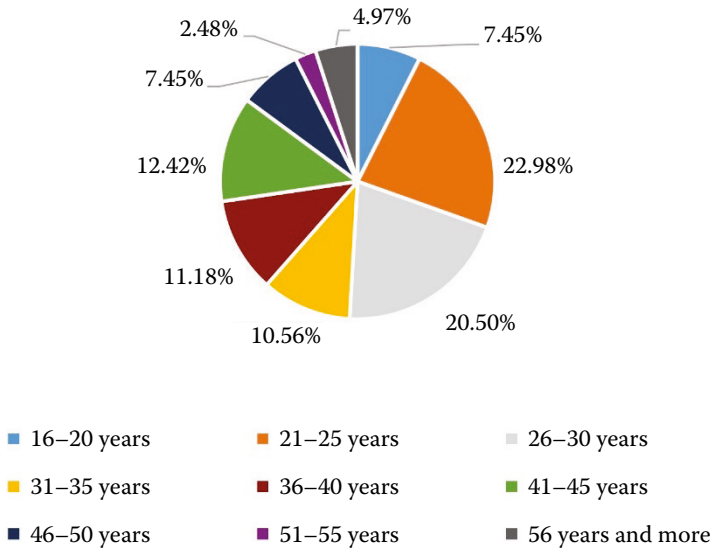

Figure 2. Age of respondents

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Table 2. Basic parameters

Operation	Mean value	Median	Mode	Frequency of mode	Min.	Max.	Standard deviation
Height (cm)	181.577600	180.00	178.00	16.00	169.00	205.00	7.329430
Weight (kg)	91.813700	88.00	100.00	13.00	60.00	145.00	17.750070
BMI	27.783730	27.613410	multiple	2.00	17.50	41.912360	4.699701
Working with the chainsaw ($h \cdot week^{-1}$)	28.267100	30.00	30.00	24.00	3.00	65.00	14.216520
Length of practice (years)	10.372670	6.00	3.00	20.00	1.00	43.00	9.151380

BMI – body mass index

erably different. The obtained data were further used to calculate the *BMI* for each respondent. The highest reached value was 41.91236, which can be considered 'obesity class III' according to the *BMI* classification. The value was reported by a respondent from the age group of 56 and older who has been working with the chainsaw for more than 40 years and approximately 30 h per week. The minimum *BMI* recorded was 17.50. The person was 200 cm high, he was working with the chainsaw approximately 8 h a day and had 4 years of experience. The value shows that the individual was 'underweight'. The average *BMI* of the respondents was 27.78373, which can be considered 'pre-obesity'. One of the research objectives was to determine whether the stress to the individual body parts of the chainsaw operators is affected by the *BMI*. The value of the calculated *BMI* for the chainsaw operators represents a wide range from 17.50 to 41.91236. The results of the statistical analysis in Table 2 clearly indicate that the value of the *BMI* has no influence on the stress of the individual body parts of the chainsaw operators. This statement is justified based on the test criterion (calculated result) which did not exceed the critical value of 1.974996 in any of the cases, indicating that a correlation did not exist.

In our research, we also monitored how many hours per week the individual respondents worked with the chainsaw. The chainsaw was, on average, used 28.2671 h per week (Table 2). However, the most frequent time of use was 30.00 h per week and the maximum length of working with the chainsaw per week was 65.00 h per week. This fact was reported by an operator from the age group of 36–40 years, who has been working with the chainsaw in the forest for 20 years. Interestingly, there was a finding that the respondent did not feel any fatigue in 16 evaluated parts of the body (out of a total of 24). He reported mild fatigue in 6 body parts and average fatigue only in two body parts (lumbar part of the back – right, and lumbar part of the back – left). The minimum time of working with the chainsaw was only 3.00 h per week. This time was reported by a respondent from the age group of 21–25 years. This great difference between the minimum and maximum time of working with the chainsaw per week is also confirmed by the standard deviation, which is 14.216520, indicating very different schedules of weekly work of chainsaw operators. Another monitored parameter of our research was the length of practice of chainsaw operators. The longest practical experience was 43.00 years. The worker is from the age group of 56 years and older and works with the chainsaw approximately 20 h per week. This respondent reported mild fatigue in most of the monitored body parts, no fatigue at all in six body parts and average fatigue in two parts of the body (upper part of the back – right and lumbar part of the back – left). The shortest reported length of practice was only 1 year. The respondent is from the age group of 21–25 years and works with the chainsaw 25.00 h per week. The most frequently reported length of practice by the respondents was 3.00 years (in 20 cases). The average length of practice with the chain chainsaw was 10.37267 years. The obtained information about the length of practice with the chainsaw and the weekly use was subjected to a statistical analysis in order to show a correlation between it and the stress affecting the individual parts of the operators' bodies, which was the second goal

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Table 3. Results of statistical analyses

Part of the body	Side	Test criterion			Critical value
		BMI	working with a chainsaw (h·week^{-1})	length of practice (years)	
Neck	right	–1.354772	0.034692	–0.079889	1.974996
	left	–1.106030	–0.061905	–0.575963	
Shoulders	right	–1.455183	–0.550044	–0.518054	
	left	–1.308590	–1.169669	–0.504207	
Upper part of the back	right	–1.715237	0.001416	–2.350654	
	left	–2.111709	–0.024683	–2.050862	
Lumbar part of the back	right	–0.872481	–1.703978	–0.504961	
	left	–0.722015	–1.081151	0.215434	
Arms	right	–1.631193	–1.404164	–2.516556	
	left	–1.419879	–1.459500	–1.808234	
Elbows	right	–0.589112	–0.681314	0.696005	
	left	0.107771	–0.582839	0.084839	
Forearms	right	–1.809223	–0.694075	–1.645278	
	left	–1.684901	–0.449891	–1.307607	
Wrists and hands	right	–1.829211	0.601738	–1.209812	
	left	–2.183874	–0.019219	–0.878296	
Hips	right	–1.553958	–1.339846	0.701225	
	left	–1.330833	–1.327319	0.667133	
Knees	right	–0.775237	1.045267	–0.068354	
	left	–0.765633	1.001409	0.414126	
Lower legs	right	–0.191656	–0.537339	–0.120721	
	left	–0.106513	–0.548079	0.434063	
Legs	right	–0.382708	–0.399678	1.032214	
	left	–0.004370	–0.637053	1.059348	

BMI – body mass index

of this research. It was found (Table 3) that the time of operating the chainsaw has no influence on the excessive stress of the individual body parts of the chainsaw operators because the test criterion (calculated result) did not exceed the critical value of 1.974996 in any of the cases, and a correlation, therefore, does not exist.

DISCUSSION

Most activities performed in the forest by chainsaw operators are carried out in uncomfortable positions (Masci et al. 2021). High physiological workload levels in chainsaw operators are connected to inappropriate body positions as well (Grzywiński et al. 2017). The basic results of the studies (Grzywinski et al. 2016; Lagerstrom et al. 2019) showed that manual work with the chainsaw correlated with a significant risk of MSD in chainsaw operators. Kim et al. (2017) informed us that nearly all the respondents in their research reported symptoms of MSD in at least one part of the body during the previous 12 months. A disturbing fact is also the existence of only a few supervision systems monitoring MSD in connection with timber logging (Lagerstrom et al. 2019).

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Lynch et al. (2014) informed us that chainsaw operators have a high prevalence of MSD which is attributed to their work postures. Chainsaw operators in forestry often reported MSD issues concerning various body parts such as the hands, elbows, shoulders, neck, and lower part of the back (Lynch et al. 2014; Grzywinski et al. 2016; Lagerstrom et al. 2019; Staněk et al. 2023a).

A study by Hagen et al. (1998) focusing on the prevalence of MSD in Norwegian forest loggers showed that 24.8% of the respondents felt pains in their lower back. A study published by Grzywiński et al. (2016) focused on chainsaw operators working in Poland, mentioned an MSD prevalence of 66.3% in the lower back, 50.7% in the wrist/hand, 45.6% in the upper back, and 37.7% in the knee. Lagerstrom et al. (2019) informed us that the prevalence of MSD in chainsaw operators was equal to 38% in the lower back, 28% in the shoulders, and 25% in the knee and neck. Kim et al. (2017) claim that the most frequently affected body parts in loggers were the lower back (49.2%) and knees (37.7%). The results published by Masci et al. (2021) indicated the increased prevalence of disorders of the upper extremities ranging from 21–50%. These values are higher as compared with research works of e.g. Bovenzi et al. (2016) and Hamgen et al. (1998), who mention values ranging from 20% to 35%.

According to Röjgren and Widell (2022), the lower part of the back is affected particularly by the body posture and by the physical load when working with the chainsaw, as these work operations are often carried out in forward-leaning and standing positions with bent legs. In felling trees, the pain in the back can be attributed to a high share of time spent by forest workers in forward bending positions. INAIL (2012) claims that delimbing and felling trees are work operations significantly connected with the risk of biomechanical overload in the lower part of the back, which was stated based on the research conducted with Italian forest loggers.

Heavy fatigue and pains in the knees are caused by the terrain conditions, steep slopes in particular. Steep slopes impair the musculoskeletal system of forest loggers who fell trees manually with a motor chainsaw and, when looking for another tree to be cut, they have to carry the equipment manually, which requires walking across steep and uneven terrains that might affect the MSD of the knees (Axelsson 1998).

The aim of this research was to find out whether the time of using the chainsaw causes excessive stress to individual body parts of forest loggers. Nieuwenhuis and Lyons (2002) did not find any significant correlation between the years of experience and the MSD prevalence in chainsaw operators. Their research revealed the same findings as our research. Latko et al. (1999) claim that forest workers with more years of experience are physically stronger and understand better the work procedures in spite of their age and years of being exposed to repeated physical movements that are considered the main cause of occupational disorders in the upper limbs. Landekić et al. (2023) informed us that all the variables relating to groups with different work experience with the chainsaw led to a statistically significant difference in the upper body posture. Masci et al. (2022) reported that workers more experienced with forest logging felt a lower physical burden. The same authors assume that the greater experience of the workers may affect their perception of fatigue.

In Lagerstrom et al. (2019), the average age of chainsaw operators was 46 years, the average *BMI* was 28, and the average length of professional practice was 22 years. Our research revealed an average *BMI* of 27.78, which agrees with their research. A difference is in the average length of the professional practice, which is 10.4 years in our research, i.e. shorter by more than a half. Lagerstrom et al. (2019) claimed that the investigation of the effect of age and work experience shows symptoms proportionally increase with increasing age and work experience in all the age groups. Pontén (1988) conducted a study with 3 600 forest loggers in Sweden in order to determine the effect of age on the MSD. His research resulted in a statement that complaints concerning MSD were quite common with no regard for age. Lynch et al. (2014) claim that age has nothing important to do with the pain in the back but rather with the pain in the neck. Miranda et al. (2002) add that the pain in the knees may be also related to age. The statements by the above-mentioned authors do not agree too much with the results of our research which found no statistically significant difference in the level of stress on individual body parts of forest loggers resulting from the effect of experience and time of working with the chainsaw.

The aim of the research was to also find out whether the *BMI* causes excessive stress to the in-

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dividual parts of the body of chainsaw operators at work. The results of our research indicate that the *BMI* value has no influence on the stress of the individual body parts of chainsaw operators. Our results correspond with the results of Malchaire et al. (2001). Lagerstrom et al. (2019) do not agree with our statement, claiming that the probability of MSD increases with increasing *BMI*.

The authors of this paper assume that the development of ergonomic elements of chainsaws has to be accommodated to the specific group of users and their physical dimensions. Kaljun and Dolšak (2012) suggest an angle between the front and rear grip to be approximately 25°, which should provide sufficient comfort to the wrist of operators in all working positions. For dimensions of the hand width clearance, they propose a minimum level of 11 cm, which is 3.4 cm more than the current minimum value. This is also agreed upon by Gejdoš et al. (2022).

CONCLUSION

In our research, we addressed 161 respondents whose body height ranged from 169.00 to 205.00 cm, and the average height was 181.5776 cm. The body weight of the respondents ranged from 60.00 to 145.00 kg. The average *BMI* value of the respondents participating in the research was 27.78373, but there were also *BMI* values reaching 41.91236 or only 17.50. The respondents were operating the chainsaw from between 3.00 h to 65.00 h per week, and most frequently 30.00 h per week. Their length of practice with the chainsaw was up to 43.00 years, and most frequently 3.00 years.

The goal of this research was to verify the effect of the *BMI* on the excessive stress to the individual body parts of chainsaw operators at work and to determine whether the excessive stress to the individual body parts of operators is affected by the time spent using the chainsaw. The obtained and processed results of our research demonstrated that neither the value of the *BMI* nor the time spent working with the chainsaw had an influence on the stress to the individual body parts of the chainsaw operators.

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