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The Magnitude of Fatigue Recorded in Individual Body Parts of Chainsaw Operators after Work

Luboš Staněk *, Jindřich Neruda and Pavel Nevrkla

Department of Engineering, Faculty of Forestry and Wood Technology, Mendel University in Brno, 613 00 Brno, Czech Republic; jindrich.neruda@mendelu.cz (J.N.); pavel.nevrkla@mendelu.cz (P.N.)
* Correspondence: lubos.stanek@mendelu.cz

Abstract: The work of chainsaw operators in the forest environment is a hazardous activity associated with great physical effort, inappropriate posture and significant strain on individual body parts. The aim of this study was to gather and evaluate data on the fatigue of individual body parts of professional chainsaw operators felling trees in the forest. The research focused on twelve body parts (eight in the upper half and four in the lower half of the body), each divided into the right and left parts. Based on the questionnaire method, 170 professional chainsaw operators working in the Czech Republic participated in this research. The questions in the questionnaire were divided into two sections, and the answers were used to draw diagrams that were consecutively analysed and quantitatively characterised based on descriptive statistics. The research results indicated that the most stressed part of the operator's body at the end of a shift was the lumbar region. The second most stressed body parts were the wrist and hands. In contrast, the neck was the least stressed part of the operator's body.

Keywords: tree felling; forestry; ergonomics; body posture; work load; working position of the body; musculoskeletal disorders

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1. Introduction

In most countries, working in the forest is one of the most dangerous occupations, with high rates of serious injuries, fatalities and occupational diseases affecting the musculoskeletal, nervous, vascular and cardiovascular systems [1,2]. Analyses of accidents show that the most critical operations in forestry are motor-manual felling and timber processing [3]. Ozden et al. [4] report that all countries providing statistics on accident rates by industry identify forestry as a sector with the highest rates. Despite the use of modern technologies and machinery, occupational accidents in forestry are frequent and often fatal, especially in felling trees [5]. For example, the U.S. Bureau of Labor Statistics (BLS) reported in 2016 that the incidence rate of non-fatal occupational accidents and occupational diseases in the logging sector was 3.6 per 100 full-time equivalent employees (FTE) [6], and in 2015, occupational accidents were responsible for 98 deaths per 100,000 FTE [7]. In 2018, timber logging was the deadliest civilian occupation in the United States, with a fatality rate of 97.6 per 100,000 FTE. This rate was 27.9 times higher than the fatality rate for all employees, which was 3.5 per 100,000 FTE [8]. In Japan, forestry accounts for the highest number of fatal injuries of any industry, with chainsaw accidents while felling trees accounting for 41–69% of all fatalities each year from 2000 to 2014 [9]. In Russia, the rate of fatal injuries from logging was estimated at 1.4 fatalities per 1 million m^3 of timber harvested [10].

The specific working conditions in forests, such as the type of terrain and slope, weather conditions, the use of various tools, low-level of mechanisation and heavy machinery, and the specific working procedures of timber logging, as well as the intensity of the manual labour, make forest work hazardous [11,12]. For these reasons, timber harvesting belongs among the most dangerous and strenuous occupations in all production

sectors [13], with various risks arising from topography and climate, difficult field conditions, heavy work equipment and environment [14]. As a result, these activities pose a very high risk of occupational accidents [15], and motor-manual logging, whether partially or fully mechanised, puts high demands on forest workers [16,17].

Although the technological progress and the deployment of harvesters and forwarders, as well as occupational health and safety systems, have significantly contributed to the creation of safer working environments in forestry [18], conventional harvesting is still widely used. Conventional logging includes trees' felling, delimbing, and cross-cutting to the required length by chainsaw operators [19]. Chainsaw operators are the most vulnerable workers in the forest harvesting process [20].

The most demanding professions in forestry are those associated with chainsaw logging (felling and conversion of trees), one of the most challenging and demanding types of manual labour [21]. This work is characterised by, among other things, uncomfortable body positions [22], movement and carrying and operating various working tools in harsh terrain [23]. Chainsaw operators are also exposed to negative physical, psychological and environmental factors due to working outdoors and the frequent use of both hand tools and machines [24]. These factors also include the impact of vibration [25,26], noise [27], dust [28], fumes [29], unnatural and uncomfortable working positions [30] and the risk of musculoskeletal disorders (MSDs).

Musculoskeletal disorders represent the most common work-related health problem. It is estimated that approximately 25 and 23% of employees in EU countries complain about backache and muscle pains, respectively. In these countries, 62% of workers are exposed to repetitive hand and arm movements, 46% to painful and uncomfortable body postures, and 35% to carrying or moving heavy loads for at least a quarter of their working time [31]. In forest harvesting, musculoskeletal disorders (MSDs) can be caused by a wide range of risk factors, such as lifting and carrying heavy loads, lack of breaks, maintaining an incorrect posture for a long time, repetitive movements and high levels of physical effort and exertion [32,33]. Physical exertion, in particular, In particular, is responsible for the development of MSDs. It is worth noting that physical exertion during motor-manual timber harvesting is measured in pulses, ranging from 110 to 132 per minute [34]. Excessive physical workload may also lead to fatigue [35], resulting in mistakes and accidents [36]. Physiological stress plays a role, too. The high physiological load of chainsaw operators is connected with the inappropriate body position during felling. The highest cardiovascular responses were recorded during felling when the fellers often had to work in postures involving moderate-to-severe trunk and knee flexion [37].

There is a wide variety of working postures that chainsaw operators have to perform during forest harvesting [38,39]. Due to the complexity of chainsaw operation, the operators also have to take uncomfortable positions that require muscle tension [23]. Therefore, positions requiring higher muscle involvement are characterised by a greater physiological load [37]. The underlying cause is the frequent maintaining of incorrect body posture when working with a chainsaw [39], which can affect the spine, among other things. On the other hand, correct posture is considered a prerequisite for a healthy life [40]. At work, people tend to change their correct posture and adopt harmful body positions due to habits developed over time. This tendency can be identified at work, especially when the work is performed in difficult terrain and involves the use of chainsaws [23].

The goal of this study was (1) to explore the prevalence of musculoskeletal symptoms in forestry workers in the Czech Republic using a questionnaire, and (2) to evaluate the pain level in individual body parts of chainsaw operators at the end of their work shift. Questionnaires were chosen because they appeared to be the most comprehensive method of collecting data on musculoskeletal disorders and their further analysis, providing valuable and reliable information on musculoskeletal symptoms. Questionnaires were used for analysing musculoskeletal symptoms in several research studies [41–44] and received a lot of attention; at the same time, they are the basis for high-impact articles with a high

citation rate. One of the reasons may also be that ergonomics plays a crucial role in the move towards sustainable forestry [45].

2. Materials and Methods

An online questionnaire was created to collect data on local musculoskeletal strain, i.e., fatigue of individual body parts, in chainsaw operators working in forestry after their shift. The anonymous online questionnaire was created in the Google Forms software (2022) and distributed to professional woodcutters. The authors of this article created the questionnaire questions. The authors drew inspiration for the questionnaire from the National Reference Workplace for Occupational Physiology and Psychology. Prior to completing the questionnaire, the respondents were informed of the purpose of collecting information for a technical paper that would be publicly available, and all agreed.

The questionnaire consisted of two parts. The first part contained "general" questions to obtain general data on the respondents and to identify possible complications or limitations in evaluating their answers.

The specific questions are listed below:

(1) Gender (male/female).
(2) Age (16–20, 21–25, 26–30, 31–35, 36–40, 41–45, 46–50, 51–55, 56 and over).
(3) Dominant hand (right/left).
(4) Height (cm).
(5) Weight (kg).
(6) How long have you worked as a chainsaw operator in timber harvesting?
(7) Approximately how many hours per week do you use a chainsaw?
(8) What type of chainsaw do you use (brand)?
(9) On which side of your body do you hold the saw when felling a tree?
(10) Do you have any health complications/ailments that could affect your performance as a chainsaw operator work? If so, what are they?
(11) Have you suffered any occupational accidents while working with a chainsaw? If so, what kind?
(12) Do you consider yourself a "physically active person"? Do you participate in sports or fitness? If so, how many hours per week approximately?

The other part of the questionnaire focused on practical data on the level of fatigue in individual body parts of chainsaw operators at the end of their work shift, during which they fell trees with the chainsaw. The respondents' task was to mark (according to the scheme in Figure 1) a level (degree) of fatigue in the specific part of their body at the end of the work shift, based on the following scale:

0: None at all
1: Mild
2: Average
3: Severe
4: Excessive

The data were collected between 13 February 2023 and 21 March 2023 from 170 respondents (professional chainsaw operators in timber harvesting), of whom 161 (94.7%) were men and 9 (5.3%) women. Most respondents were aged 21–25 (24.1%), followed by 26–30 (19.9%), 41–45 (12.3%), 31–35 (11.8%), 36–40 (10.6%), 16–20 and 46–50 (both categories account for 7.1%), 56 and over (4.7%) and 51–55 years (2.4%). There were 146 right-handed (85.9%) and 24 left-handed (14.1%) participants. However, this did not affect the obtained results as all respondents held and used the chainsaw on the right side of their body when working.

The questionnaire responses were subsequently transferred from the Google Forms software to Microsoft Excel 2016 (Microsoft Company, Redmond, WA, USA), where the data were split into individual sheets according to individual body parts and processed. The body parts were further divided into two groups: upper body (neck; shoulders; upper back; lumbar; arms; elbows; forearms; wrists and hands) and lower body (hips; knees;

shanks; legs). Thus, the data split was assigned sequence numbers according to the date respondents returned the questionnaires. The questions in the first part of the questionnaire were processed separately because the answers differed.

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		

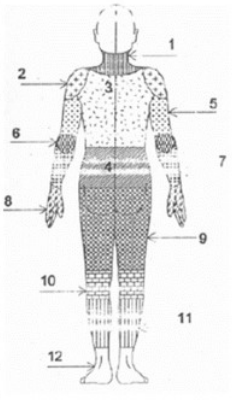


Figure 1. Scheme of muscle strain assessment (according to SZÚ—National Reference Workplace for Labour Physiology and Psychology).

In the second part of the questionnaire, questions were processed based on filtering the necessary sections, i.e., filtering numbers or text. Values for specific body parts were summed up and recorded in tables used to create well-arranged diagrams. The diagram values represent responses to the magnitude of fatigue in the specific body parts, consecutively converted to percentages and rounded to two decimal places, i.e., the diagrams show the percentages of each respondent's responses for a specific level of fatigue (none at all; mild; average; severe; excessive) in a particular body part. It should be noted that each assessed body part was divided into a right and a left side. The values shown in the diagrams for a specific body part may not be identical for the right and left sides, as respondents may experience different levels of fatigue on the right and left sides of a given body part. The diagrams with ordinal data were then evaluated using descriptive statistics and characterised quantitatively.

3. Results

The neck was the first body part where the respondents reported fatigue at the end of a shift (Figure 2). The results indicate that more than 62% of chainsaw operators felt "No fatigue at all" in this part of the body, and a fifth of respondents felt only "Mild" fatigue. The "No fatigue at all" rating for the neck is the highest of all the body parts evaluated by the respondents. 9.41% of respondents reported an "Average" fatigue in this body part, equally on the right and left sides. Only seven respondents out of all inquired persons felt "Severe" fatigue in the neck area, of whom 57.14% felt the same level of fatigue on both the left and right sides of the neck. The majority of these respondents spent 30 h per week working with a chainsaw and felling trees. The neck was the only part of the body where no respondents felt "Excessive" fatigue. Figure 2 shows that the neck area was the least strained part of the chainsaw operators' bodies during their work performance.

The following body parts were the shoulders (Figure 3). Most respondents reported feeling "No fatigue at all" after felling (57) or "Mild" fatigue (51), distributed equally between the right and left shoulders. "Excessive" or "Severe" fatigue in the shoulders was reported by 11 respondents, indicating that the shoulders were identified as the second least tired part of the upper body after felling. "Excessive" fatigue was reported by three respondents (two in the left shoulder and one in the right shoulder). These respondents claimed to feel "Severe" fatigue in the opposite shoulder. One of them (age category 56+), who had been working as a chainsaw operator for ten years, reported visiting a doctor to receive local injections to relieve shoulder pains. 12.35% of respondents reported

experiencing "Average" fatigue in the shoulders, equally distributed between the left and right shoulders.

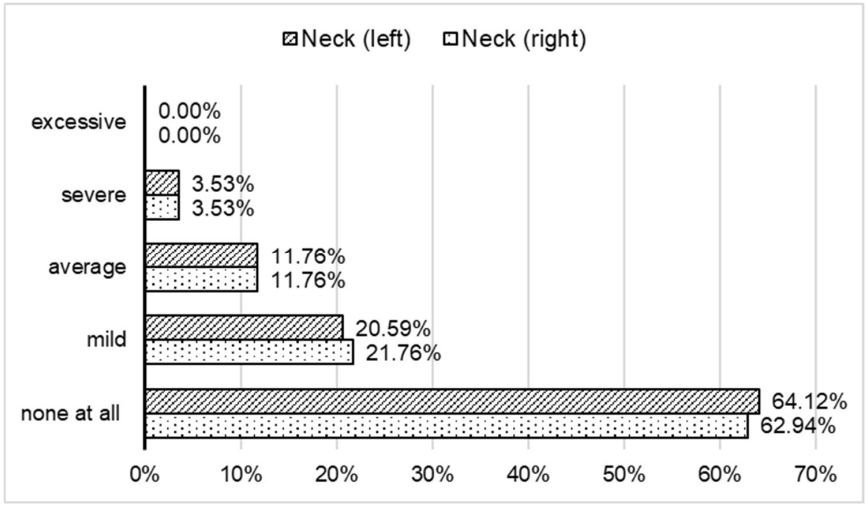


Figure 2. Levels of neck fatigue among chainsaw operators.

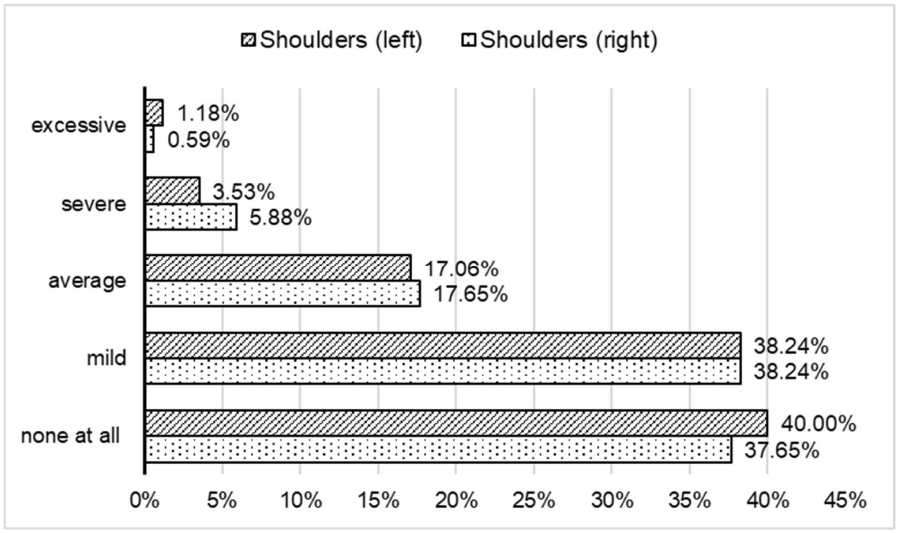


Figure 3. Levels of shoulder fatigue among chainsaw operators.

Figure 4 shows the results of fatigue in the upper part of the back of the chainsaw operators, indicating that the respondents felt the least "Excessive" fatigue in this part of the upper body (six respondents); of these, 83.33% experienced "Excessive" fatigue on both the left and right sides of the body. These workers used mainly medium chainsaws and spent approximately 40 h per week felling trees. Compared to other parts of the upper half of the body, this area was the second most "excessively" tired part of the body. On the other hand, the majority of chainsaw operators (72) experienced "No fatigue at all" in the upper part of the back on at least one side of the body (left or right) after work, with 87.50% of these operators reporting "No fatigue at all" on either side of their back. Less than 33% of the chainsaw operators experienced "Mild" fatigue.

The lumbar part of the back (Figure 5) was identified as the most stressed part of the operator's body, with more than half of the respondents experiencing "Excessive", "Severe" or "Average" fatigue on at least one side of this body part after work. Compared with the other body parts, the respondents reported the highest score in the "Excessive", "Severe" and "Average" fatigue on at least one side of the body. "Excessive" fatigue was reported by

eleven respondents (6.47%), "Severe" fatigue by 28 respondents (16.47%), and "Average" fatigue by 68 respondents (40.00%).

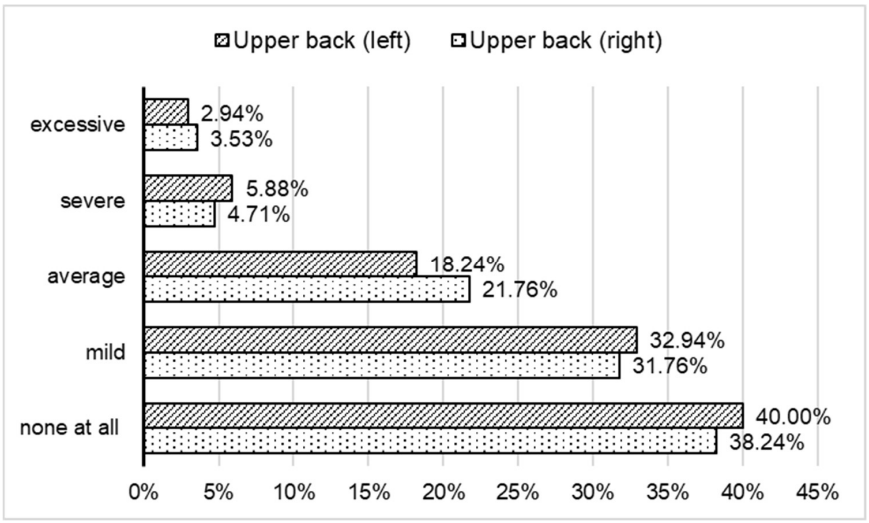


Figure 4. Levels of upper back fatigue among chainsaw operators.

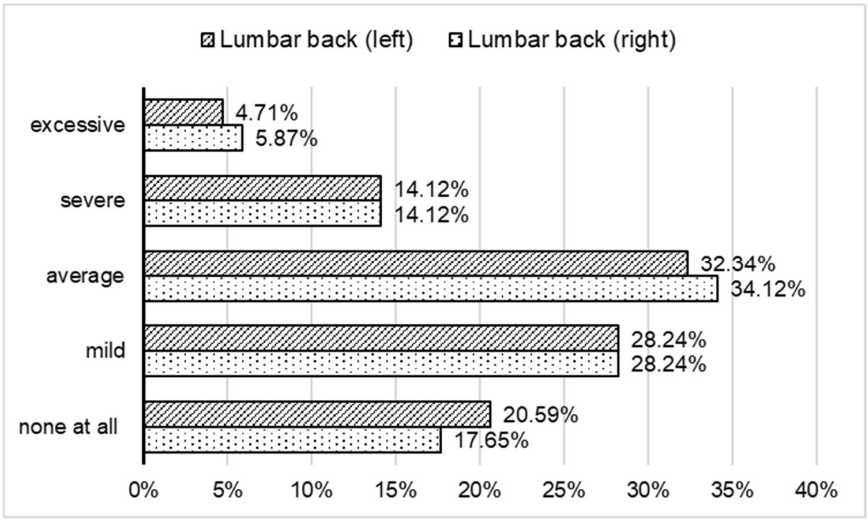


Figure 5. Levels of lumbar back fatigue among chainsaw operators.

On the other hand, "No fatigue at all" in the lumbar region was claimed only by 22.35% of respondents, which was the lowest value for this level of classification compared to the other body parts. "Mild" fatigue in the lumbar region after felling trees was reported by 32.94% of chainsaw operators.

The fatigue assessment for individual body parts also included the arms (Figure 6). In fact, the arms were identified as the body part with the third lowest rating of "None at all" fatigue and the second lowest rating of "Average" fatigue. Together with the shoulders, the arms have the second lowest rating of "Excessive" fatigue compared to the other upper body parts. Only two respondents reported "Excessive" fatigue in this part of their body, i.e., 1.18% of all respondents. They were the same workers who also reported "Excessive" fatigue in their shoulders. The most common response was "No fatigue at all" (41.76%). 8.24% of respondents reported "Severe" fatigue in this part of their body.

The chainsaw operators also assessed the fatigue they felt in the elbow (Figure 7). Respondents claimed to experience the second highest "No fatigue at all" score compared to the other upper body parts dy. The same applied in summing up "No fatigue at all" and "Mild" fatigue; more than 80% of respondents reported one of these two categories.

"Excessive" fatigue was reported by four saw operators (2.35% of respondents), half of whom claimed "Excessive" fatigue in both the left and right elbows. One of these saw operators felt "Excessive" fatigue in the right elbow, while "No fatigue at all" in the left elbow. The respondent is a right-handed person aged 51–55 years, suffering from overweight according to BMI, who has been operating the chainsaw for 30 years, using it approximately 35 h a week. "Severe" and "Average" fatigue in the elbows was reported by 5.29 and 25.29% of the respondents, respectively.

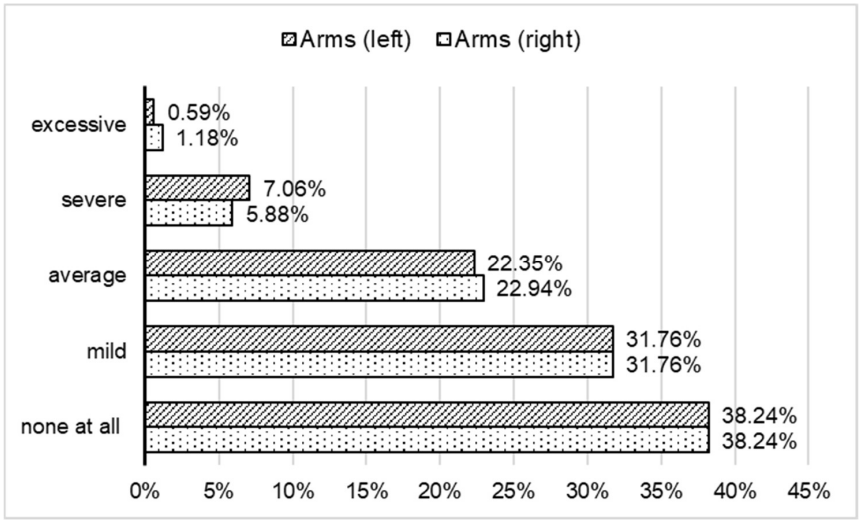


Figure 6. Levels of arm fatigue among chainsaw operators.

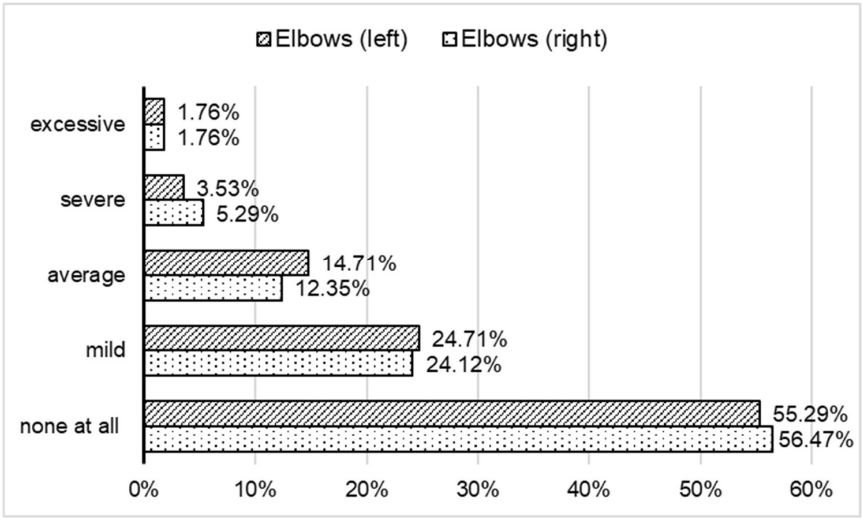


Figure 7. Levels of elbow fatigue among chainsaw operators.

Figure 8 shows fatigue in the forearms of chainsaw operators at the end of their shift. Most respondents (86) reported feeling "No fatigue at all" in this body part. This is the third-highest rating for the upper body. "Excessive" fatigue in the forearms was reported by the lowest number of respondents (5), "Mild" fatigue by 59 respondents, "Average" fatigue by 40 respondents and "Severe" fatigue by 11 respondents. Comparing the responses to all fatigue levels reported by saw operators in both the left and right forearms, 5.41% more workers reported "No fatigue at all" in the left forearm than in the right, 20.45% of workers claimed "Mild" fatigue in the right forearm, 9.68% felt "Average" fatigue in the left forearm, and 25.00% reported "Severe" fatigue in the left forearm than in the right forearm. The same number of respondents reported "Excessive" fatigue in both the left and right forearms.

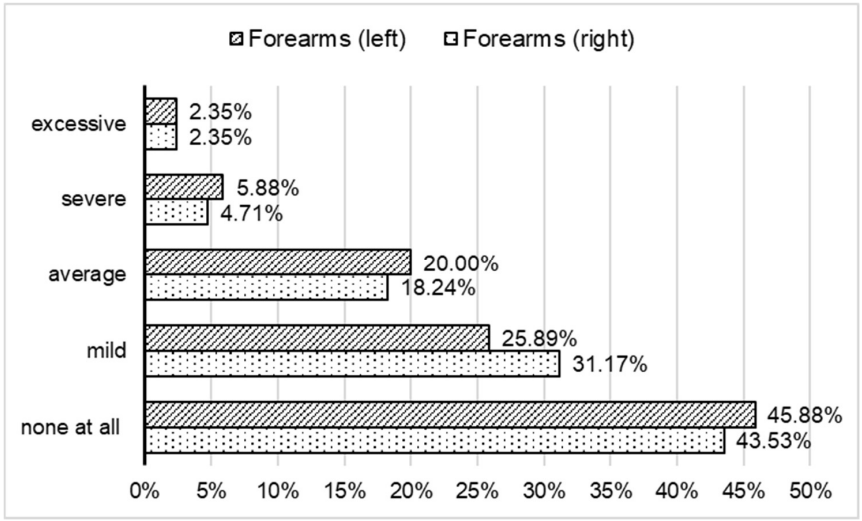


Figure 8. Levels of forearm fatigue among chainsaw operators.

The last assessed upper body parts were wrists and hands (Figure 9), representing the second most stressed body part in chainsaw operators. This is evident from the research results, as the sum of "Excessive" and "Severe" fatigue values is the second highest of all body parts rated by the respondents. The sum of "No fatigue at all" and "Mild" fatigue is the second lowest of all the body parts rated. "Average" fatigue had the third highest score compared to the other body parts. "Average" fatigue in at least the left or right wrist and hand was reported by 46 respondents (27.06% of all respondents). This fatigue level was most common among respondents aged 21–25 (26.09%).

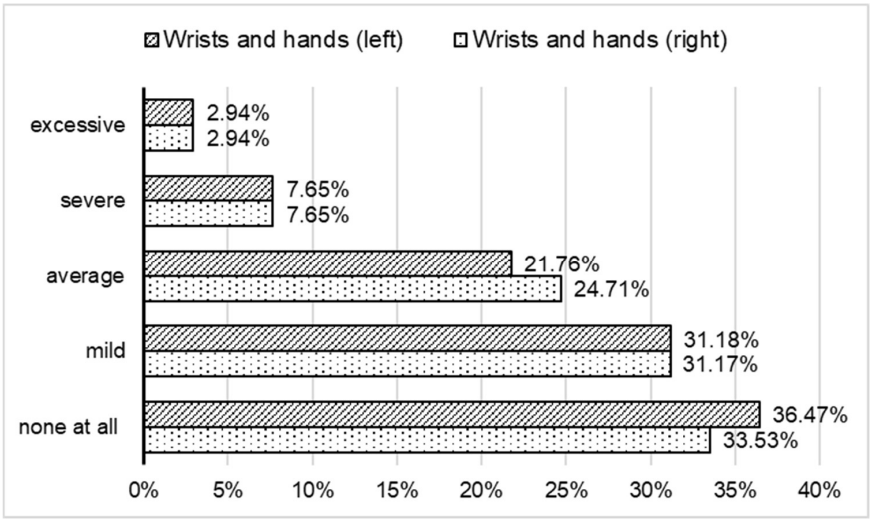


Figure 9. Levels of fatigue in the wrists and hands among chainsaw operators.

The first part of the lower body to be assessed by the chainsaw operators was the hips (Figure 10). Most reported feeling "No fatigue at all" in their hips after work. The "No fatigue at all" response was also the highest for the entire lower body and the second highest for the entire body. The lowest number of respondents reported "Mild" and "Average" fatigue compared to the other lower body parts. On the other hand, respondents assigned the highest score to "Severe" fatigue compared to the other lower body parts. Only three respondents felt "Excessive" fatigue in the hips; two of them on both sides of the hip. The remaining respondent experienced "Excessive" fatigue only on the right side and "Severe" on the left side. The respondent was 41–45 years old, had worked as a woodcutter for 25 years, and suffered from a herniated disc.

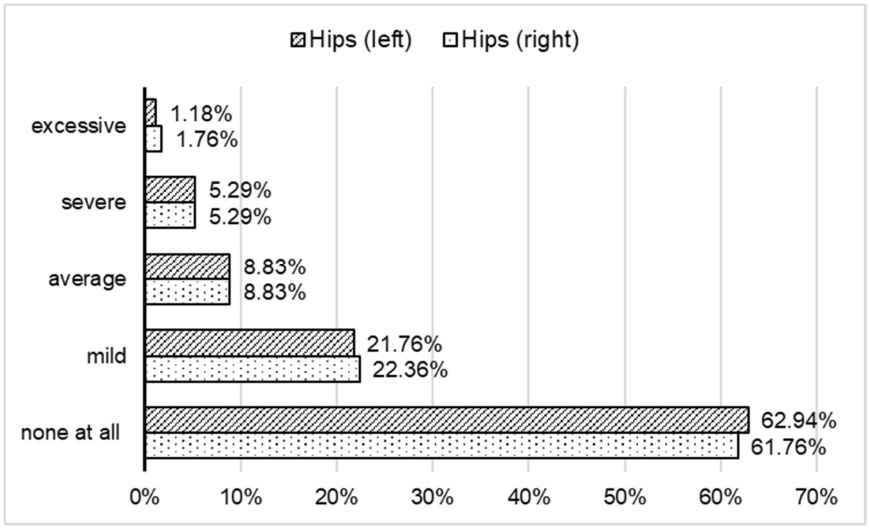


Figure 10. Levels of hip fatigue among chainsaw operators.

Figure 11 shows the fatigue that respondents classified in the area of their knees. In fact, the knees were rated as the second most "Excessively" strained body part, as well as the most "Excessively" strained part of the lower body. This level of fatigue was reported by seven respondents, representing 4.12% of all participants. Six respondents experienced "Excessive" fatigue in both knees. One respondent claimed only fatigue in the right knee and "Mild" fatigue in the other. The woodcutter was 51–55 years old, had worked in the forest for 30 years, and spent approximately 35 h per week felling trees. At the same time, the woodcutter reported that he had suffered a broken leg in the past (without additional information); this may have been a factor in his different classification of fatigue in the left and right knee. Respondents mostly claimed to feel "No fatigue at all" in this body part.

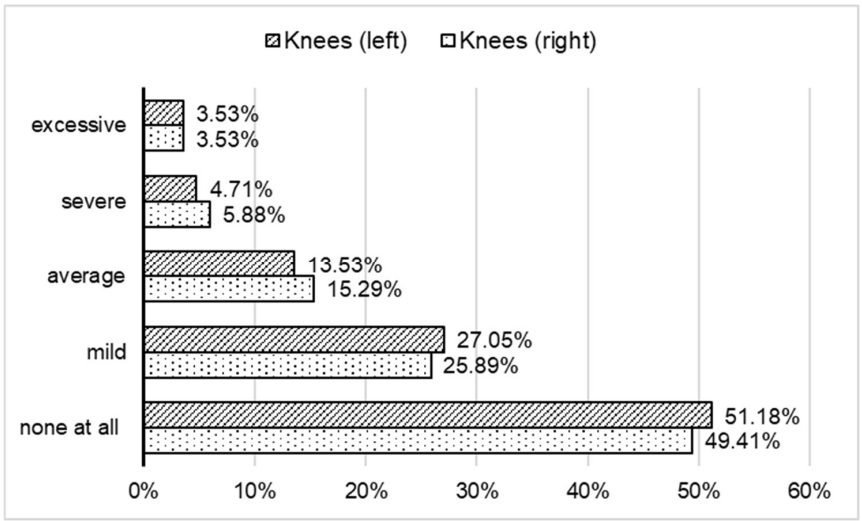


Figure 11. Levels of knee fatigue among chainsaw operators.

Other parts of the body where fatigue was evaluated were the lower legs (shanks) (Figure 12). The research results showed that the lower legs experienced the least "Excessive" and "Severe" fatigue among chainsaw operators compared to other lower body parts. "Excessive" fatigue was reported only by 1.18% of the woodcutters (two respondents). "Severe" fatigue was mentioned by 4.12% of saw operators (seven respondents). Therefore, the lower legs can be considered the least stressed lower body part. "No fatigue at all" or "Mild" fatigue at the end of the work shift was reported by more than 85% of saw operators who participated in the research.

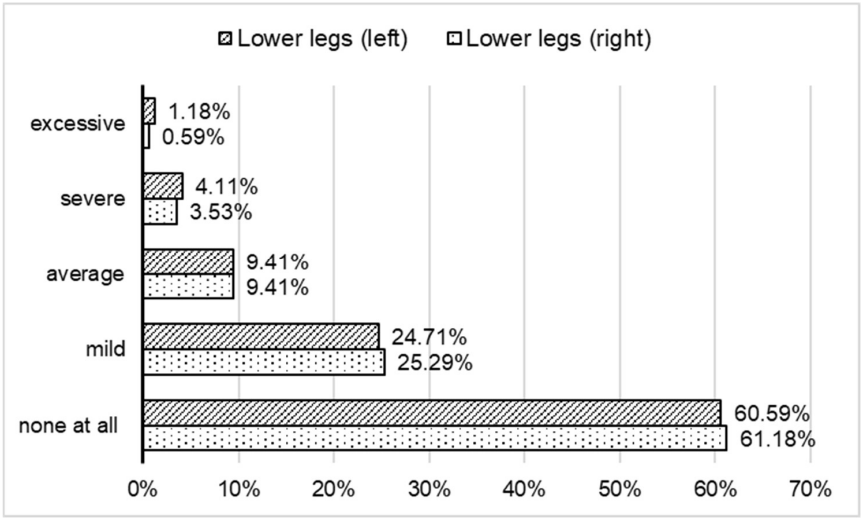


Figure 12. Levels of lower leg fatigue among chainsaw operators.

The legs were the last body part to be rated for fatigue (Figure 13). Most respondents reported "No fatigue at all" in this body part. Compared to the other lower body parts, "No fatigue at all" in the legs was the lowest. On the other hand, the highest scores were obtained by "Mild" and "Average" fatigue compared to other lower body parts. Two respondents reported "Excessive" fatigue in both the left and right legs. One claimed "Excessive" fatigue in all lower body parts. This respondent was 21–25 years old, had normal weight according to BMI (not underweight, overweight or obese) and had worked as a woodcutter for two years. He did not mention any health problems that might affect his work performance. "Severe" leg fatigue was reported by 5.29% of the saw operators surveyed.

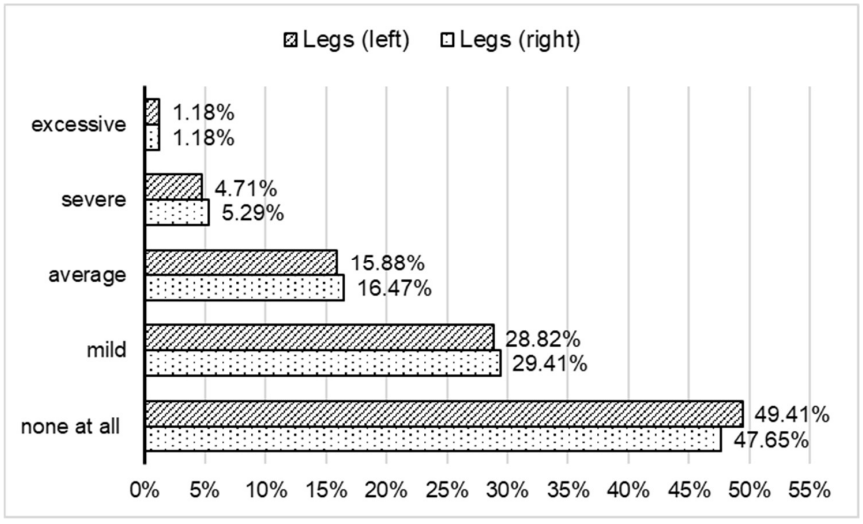


Figure 13. Levels of leg fatigue among chainsaw operators.

4. Discussion

Occupational musculoskeletal disorders continue to attract the attention of workers, researchers, and organisations. Reasons include temporary or permanent incapacity to work, reduced productivity, increased compensation costs, and symptoms such as pain, numbness, and tingling [42,46]. The occupational nature of the problem is also of concern, as chainsaw operators suffer from a high incidence of musculoskeletal disorders [38], with personal factors such as weight, height, dominant hand, age, smoking and drinking habits not playing a direct role in the development of musculoskeletal symptoms [47]. Grzywinski, W. et al. [48] add that the MSD symptoms occurrence among chainsaw operators constitute

a serious health problem. The seriousness of MSD among woodcutters is also demonstrated in [48], where only 6% of the 353 chainsaw operators reported no symptoms in some of the body parts evaluated (neck, upper back, lower back, shoulders, elbows, hands/wrists, hips/thighs, knees. legs/ankles) in the last twelve months. MSD symptoms in one body part were reported by 6.1% of respondents, symptoms in two and three areas by 9.3 and 12.8%, respectively, and symptoms in four or more body parts were claimed by 65.2%.

The results of our research revealed that the most strained part of the chainsaw operator's body at work is the lumbar back. The observation is consistent with the research of [48], who published that the lumbar back was most exposed to the risk of MSDs among woodcutters. A considerable incidence of lower (lumbar) back disorders among Croatian woodcutters was also reported in [49]. In Sweden, a group of 3600 chainsaw operators was monitored [50]. Five out of ten reported lower back pain. Another study of woodcutters in Scandinavia corroborated our research findings, i.e., that the main health problem of chainsaw operators was the lower back [51].

The most frequently reported musculoskeletal disorders in woodcutters are lower back, hands and wrists, and knees [52]. This finding was confirmed by [53], who studied a group of 77 Polish woodcutters; the fatigue symptoms reported were mainly pain in the lower back, hands, shoulders and knees. Another research study conducted by authors [48] confirmed that, in terms of individual body parts, the most common fatigue symptoms among chainsaw operators were pain in the lower back (66%), wrists/hands (50%), and upper back (46%). The same authors add that MSD symptoms of upper limbs in woodcutters constitute a significant health problem. In their research, more than half of the respondents reported pain in the hands and a third reported pain in the shoulders. In Sweden, musculoskeletal problems were studied in 3,600 chainsaw operators [50]. Two out of ten workers reported pain in the shoulders, two in the knees and two in the hips. Refs. [51,54,55] add that chainsaw operators exhibit a high frequency of pains in the shoulders and arms due to risk factors associated with incorrect and restricted postures. The data recorded in our research is largely consistent, as the wrists and hands represented the second most strained part of the saw operator's body. This is because, in all activities, the hands and wrists are exposed most to the continuous load while supporting, holding and directing the running chainsaw [52]. In our research, the knees were found to be exposed to the second highest "Excessive" fatigue level, and, at the same time, the highest "Excessive" fatigue in the lower body. This means that our results are in line with the findings of [48,50,53], who also stated that knees were another body part with a high frequency of MSD symptoms (36.0% left knee, 39.4% right knee). This may be caused, for example, by prolonged standing to maintain a stable position at work, putting long-term strain on both knees. Also, knees bear the constant load of the operator's body and chainsaw in steep terrain [52]. This explains why 4.12% of chainsaw operators in our study experienced "Excessive" (i.e., the greatest possible) fatigue in their knees.

The reasons why the lumbar back is the most strained part of a saw operator's body, and why chainsaw operators experience the most fatigue and pain there, was analysed by [56], who claimed that problems with the lower back were commonly associated with hard manual labour and lifting heavy loads. It is related to the working posture, the static load associated with operating the chainsaw and the lifting and moving of heavy weights. Most of the operations are performed in uncomfortable positions. Such positions are most frequently observed at felling trees (highly bent or bent and twisted back) [57]. Ref. [58] adds that the work of chainsaw operators involves the delimbing and felling of trees and represents, therefore, a significant risk of biomechanical overloading of the lower back, as the lower back is affected by the posture and static load developed when using the chainsaw [52]. At motor-manual forest harvesting, low-back pain has also been attributed to the length of time saw operators spend in a forward bend posture [59].

Ref. [51] demonstrated that woodcutters experienced fatigue and pain in the neck. Ref. [60] explained that occupations with a fixed posture and repetitive tasks were often associated with neck problems. Ref. [52] adds that the neck area is overloaded not only by

holding the chainsaw but also by the constant static load of pushing the chainsaw when cutting logs. Our research results differ from the statements of [51], as our research has demonstrated that the neck is the least strained part of the saw operator's body at work. This is also evidenced by more than 62% of the woodcutters reporting "No fatigue at all" in this body part.

Incorrect working postures, hazardous working conditions, frequent injuries and occupational diseases are permanent risks to maintaining employees' working ability and health [61]. These problems can be minimised through efficient communication and training, relationship and trust building, awareness raising, and the availability of a risk reporting system. Ref. [62] adds that short breaks for active relaxation with light muscular activities should be introduced because regularly scheduled 10-min breaks every 60 min of work help the workers recover from the effects of fatigue [62]. Another way to reduce the risk of incorrect postures and strains on individual body parts of chainsaw operators is to introduce (where possible) extensive mechanisation in forest harvesting [63].

The study results show that chainsaw operators working in the Czech forests perform a job subject to a high risk of occupational musculoskeletal disorders. Determining the magnitude of fatigue in individual body parts is subjective in this study. Although the fact may cast some doubt on the reliability of the results, it may indicate genuine problems in the specific parts of the human body when felling forest trees.

5. Conclusions

The research results have indicated that the most strained part of the chainsaw operators' bodies at the end of their work shift is the lumbar region of the back. The least strained part of their body during logging operations is the neck. This is evidenced by more than 62% of the chainsaw operators involved in this research who reported "no fatigue at all" in the neck area. The neck was also the only body part where chainsaw operators did not experience "Excessive" (i.e., maximum) fatigue.

The wrist and hands were the second most strained part of the saw operator's body. Shoulders were classified as the second least strained upper body part. The knees were rated as the body part with the greatest "Excessive" fatigue, as well as the most strained lower body part. The least strained part of the lower body was the lower legs. The study results also indicate that, compared to the other lower body parts, the lower legs experience the least "Excessive" and "Severe" fatigue.

There is a wide variety of ergonomic risks associated with forest logging. Therefore, further research studies focusing on this issue would be appreciated in the future as one of the ways to inform and warn professional woodcutters about possible risks, not only ergonomic ones.

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