Published in final edited form as:
Safety (Basel). 2019 ; 5(2): 23. doi:10.3390/safety5020023.

Active Surveillance of Musculoskeletal Disorder Symptoms in the Development of Safety Interventions for Professional Loggers

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Abstract

Logging is one of the most dangerous occupations in the world. Logging tasks, whether they consist of operating a chainsaw, operating a mechanized harvester, or driving logging trucks, have an influence on the types of hazards and injuries among professional loggers. Using the Standardized Nordic Questionnaire, we investigated the 12-month period prevalence of musculoskeletal disorder symptoms (MSS) among professional loggers in the mountainous region of Montana. We also differentiated the prevalence of MSS based on logging system-type accounting for demographic and workplace covariates. Based on data from 743 professional loggers in Montana, loggers using conventional felling practices with chainsaws were more than twice as likely to report MSS (Odds Ratio (OR): 2.24 (1.07–4.69)) than those using mechanized logging equipment. In addition, increased MSS scores were associated with conventional harvesting systems, increased years of experience, and increased BMI. The active surveillance of MSS among professional loggers in Montana resulted in recommendations for safety interventions. The safety interventions included a greater mechanization of logging tasks and early career training on the heavy equipment used in logging operations.

Keywords

musculoskeletal symptoms; work-related injuries; logging hazards; Standardized Nordic Questionnaire; Montana

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Author Contributions

Conceptualization, E.L. and J.R.; formal analysis, E.L., S.M., W.B., and J.R.; funding acquisition, E.L., S.M., and J.R.; methodology, E.L., S.M., W.B., and J.R.; project administration, E.L. and J.R.; supervision, S.M., W.B., and J.R.; writing—original draft, E.L.; writing—review and editing, E.L., S.M., W.B., and J.R.

Conflicts of Interest

The authors declare no conflict of interest.

1. Introduction

Logging is the process of felling and processing trees to produce timber and pulp that supplies the world's markets for furniture, construction materials, paper, and other products. The practice of logging ranges from individuals harvesting fuelwood to large-scale commercial timber operations (professional loggers). There are few surveillance systems in place regarding musculoskeletal disorders, injuries, and deaths related to logging, most of which are inadequate, making comparisons and data aggregation difficult. The reliable data that does exist suggest that forestry-related work is among the most hazardous of all nonmilitary occupational activities in the world [1,2,3,4].

Within the United States (U.S.), logging is one of the most dangerous occupational sectors in terms of mortality [5]. The U.S. Bureau of Labor Statistics reported that the occupational fatality rate for logging was nearly 40 times the fatality rate for all other occupations [6]. Interestingly, in terms of injury rates in the U.S., the logging industry had lower rates than all other industries combined (2.3 per 100 full-time equivalent (FTE) vs. 3.3 per 100 FTE, respectively) [7]. The stark differences between the relative mortality and morbidity rates for the logging sector in comparison to all occupational sectors may be due to the severity of injuries leading to death in logging as well as to the underreporting of less significant injuries as reported in both logging and construction industries [8,9]. Near-miss incidents, which may indicate a future risk of injury, are also significantly underreported in the forestry industry [10].

Within the logging industry, injury and mortality rates and types of risk vary based on regional characteristics, job tasks, and logging system type. The logging system is the configuration of equipment, machines, and processes that interact with workers in various job tasks to farm and harvest trees. There is a wide range of equipment configurations and job tasks in the industry. The choice of equipment and logging system employed is dependent on the terrain and region of the harvest, as well as the resources of the contracted logging company. There are two primary logging systems for felling trees: conventional chainsaw logging and mechanized harvesting (MH) with heavy mechanized equipment (Figure 1a,b) [11]. In conventional harvesting (CH), trees are felled, delimbed, and cut to length by sawyers (chainsaw operators) using chainsaws [11]. Hookers/chokesetters may be a part of either conventional or mechanized harvesting systems and are responsible for manually attaching cables to the logs that will be hauled from the felling site to the truck-loading site above. In contrast to CH systems, MH systems use heavy equipment that fells, delimbs, and cuts the tree (log) to the desired length [11]. Many researchers studying logging safety suggest that companies transitioning from CH to MH should have fewer injuries and fatalities associated with logging [12,13,14]. Injures common in CH practices include acute injuries due to workers being struck by trees and lacerations/amputations from chainsaw use [15]. Chainsaw-related injuries are most common to the hands and upper leg leading to fatalities and a range of traumatic injuries with significant amounts of flesh and bone loss [16]. In addition, conventional felling systems are associated with chronic disorders such as hearing loss, hand-arm vibration syndrome, carpal tunnel syndrome, and other musculoskeletal disorders from persistent chainsaw use [13]. An analysis of the injury claim data from companies before and after mechanization indicated a significant decrease in injury claims when companies transitioned from conventional chainsaw felling to mechanized harvesting using feller-bunchers [17].

In addition to changes in the injury rates, type, and severity, industry modernization and mechanization has led to increases in productivity and longer working hours [12]. While mechanization has allowed loggers to harvest more trees at a faster rate, mechanized systems have been associated with increased productivity pressure and excessive shift length compared to conventional harvesting [13]. Additionally, the increased use of heavy equipment has unfortunately led to increases in the rates of lower extremity injuries related to jumping or falling off equipment.

Logging work in the mountains of Montana is especially hazardous due to steep terrain, extreme weather (cold) conditions, and remote work locations [5,15]. Logging injuries and fatalities in this region are an ongoing challenge for forestry companies and logging associations [15]. The combination of unique characteristics in the region contribute to differences in the logging techniques used, workplace demographics, and occupational safety culture compared to logging operations in other regions within the U.S. and other developed countries. In Montana, the transition to mechanized logging systems has been delayed due to steep terrain conditions and environmental regulation. Thus, the diversity of logging systems in Montana presented an opportunity to study the differences in the work tasks and musculoskeletal disorder symptoms (MSS) frequency among loggers in conventional and mechanized logging systems.

The purpose of this study was to investigate the 12-month period prevalence of MSS among professional loggers in Montana and to differentiate the prevalence based on the logging system types while accounting for demographic and workplace covariates. This form of active surveillance of MSS among professional loggers in Montana was needed to develop recommendations for safety interventions.

2. Materials and Methods

2.1. Data Acquisition

A questionnaire was administered to loggers participating in a federally mandated annual emergency first-aid training workshop in the U.S. state of Montana. The Montana Logging Association sponsored the training sessions, which were located at various locations across the state, to professional loggers. The questionnaire consisted of three different sections: demographic information, perceptions of workplace conditions and job factors, and a musculoskeletal disorder symptoms (MSSs). Participation in the questionnaire was voluntary and anonymous. Compensation was not provided to participants completing the questionnaire. All loggers in attendance at the workshops were eligible for participation. To determine the 12-month period prevalence of MSS among the logging cohort, a modification of the Standardized Nordic Questionnaire (SNQ) was administered [10]. The SNQ was commissioned by the Nordic Council of Ministers in response for the need for a standardized method for obtaining, recording, and analyzing musculoskeletal symptoms among occupational cohorts [18,19]. The SNQ was developed to assess MSS of the low back, neck and shoulders, and upper and lower extremities [18]. The modified questionnaire administered in the present study included three questions in reference to nine anatomical regions of the body (neck, upper back, low back, shoulders, elbows, wrist/hands, hip/thighs, knees, and feet). In reference to the nine anatomical regions, the first questions asked, “During the last 12 months have you had a job-related ache, pain, or discomfort?”; the second question asked, “During the last 12 months, has this ache, pain, or discomfort prevented you from doing your day’s work?”; and the third question asked: “During the last 12 months, have you seen a physician or physical therapist, etc. for this pain, ache, or discomfort?” For each question, the participants checked either yes or no for each of the nine anatomical regions.

The demographic information collected with the questionnaire included sex, age, height, weight, and education level. The job information collected by the questionnaire included primary logging system type used, hours worked per week, months worked per year, and years employed in the logging industry.

2.2. Data Analysis

The means, standard deviations, and frequency statistics were calculated for all demographic variables. The body mass indices (BMI) were calculated from the respondents’ heights and weights and categorized according to guidelines published by the National Institutes of Health [20]. The years of experience in the logging industry was divided into decades of experience. The hours worked per week was divided into three different categories: less than full time (<40 hrs/week), full time (40–60 hrs/week), and overtime (>60 hrs/week). Finally, the number of months the logger worked per year was divided into two groups, one group for loggers working the full season (nine months or more) and a group working only a partial season (less than nine months). Frequency statistics were calculated to determine the 12-month period prevalence of MSS in the overall population and by the logging system type. Two binary variables were created based upon the results of the SNQ to identify workers who experienced MSS in any anatomical area (Yes/No) or who missed work due to MSS in the past 12 months (Yes/No). T-tests were performed to determine if loggers involved in conventional versus mechanized harvesting operations were statistically similar in terms of age, BMI, years of experience in the logging industry, hours worked per week, and months worked per year. Chi-square tests were performed to determine if there were significant differences in the prevalence of MSS in each anatomical region based upon logging system type (conventional versus mechanical). A continuous variable, MSS Score, was created for each respondent by summing the number of anatomical areas with a reported MSS. The MSS Score, therefore, ranged from zero to nine (corresponding to symptoms in all nine anatomical regions). A t-test was performed to determine if there was a significant difference in the MSS Score between loggers using conventional versus mechanized harvesting systems. A multivariable logistic regression was performed to determine if the demographic and workplace covariates identified above were associated with MSS or missed work days due to MSS. A Poisson regression was performed to determine if the same demographic and workplace factors were associated with the MSS Score. The following covariates were identified, which potentially confound the relationship between the logging system type and MSS, the days missed due to MSS, and the MSS

Score: age, BMI, years employment in the logging industry, hours worked per week, and months worked per year.

The data analysis was performed using SAS 9.4 [21]. A statistical significance was based upon $p < 0.05$. The Research Integrity and Compliance Review office at the author's university approved the study methods and analyses but also determined that the study was exempt from consent procedures due to the anonymous nature of the data.

3. Results

A total of 1059 workers attended the training workshops and were provided the opportunity to complete a questionnaire. Seven hundred and forty-three questionnaires were completed and returned for an overall response rate of 70.2%. The demographic information of the respondents is presented in Table 1. The mean number of years working in the logging industry (experience) was 22.0 (SD = 14.1), and the mean number of hours worked per week in logging was 47.1 (SD = 15.5). Most workers (with a positive response to the logging system demographic question) identified their primary logging system type as mechanical felling (84%) and 16% of respondents identifying that they primarily used conventional chainsaw felling.

There were statistically significant differences in the average number of hours worked per week and the average number of months worked per year between conventional and mechanical loggers (Table 2). Workers in conventional systems, on average, worked 8.6 hours less per week ($p < 0.05$) and worked 0.7 fewer months per year ($p < 0.05$) compared to workers in mechanical systems. No significant differences were found between the age, BMI, or years of experience in the logging industry between conventional and mechanical loggers.

The anatomical area with the highest 12-month period prevalence of MSS for all loggers was the low back (38.1%), followed by the shoulders (27.6%), neck (24.8%), and the knees (24.7%) (Table 3). Although not statistically significant, workers in mechanized harvesting operations had a higher prevalence of neck and upper back MSS than conventional chainsaw loggers. However, loggers using chainsaws for felling trees had a higher prevalence of MSS in every other body area. No significant difference was found in the MSS score (mean number of MSS) between workers using conventional and mechanized harvesting.

The multivariable logistic regression analysis (Table 4) resulted in a model in which loggers employed in conventional harvesting systems had over two times the risk of any injury compared to mechanized logging system workers (Odds Ratio (OR): 2.24, 95% Confidence Interval (CI) 1.07–4.69). In addition, workers with 21–30 or 31–40 years of experience in logging had more than three times the risk of experiencing MSS in any body area in comparison to workers with less than 11 years of experience (Table 4). Based on the multivariable analysis, there were no statistically significant variables indicating an increased risk of missing work due to MSS.

The results of the Poisson regression for the MSS Score indicated that the primary type of logging operation, BMI, and years of experience in the logging industry were significantly associated with the MSS score (Table 4). The log estimate of the MSS score for loggers using a conventional chainsaw versus mechanical systems was 0.26, which corresponds to a 1.29 increase in the expected MSS score. The expected MSS score for workers with a BMI falling into the overweight range (25.0–29.9 kg/m [20]) was 0.68 points higher than workers with a BMI in the normal range (18.5–24.9 kg/m [22]) (log estimate: −0.39 (−0.60–−0.1)). The expected MSS score for workers with a BMI in the obese range (>29.9 kg/m [23]) was 0.70 points higher than workers with a BMI in the normal range (log estimate: −0.35 (−0.57– −0.13)). With greater levels of experience in the logging industry, there was a significant increase in the predicted MSS score in comparison to the referent group. Workers with 40 or more years of experience had the highest log estimate of MSS score (1.07), followed by the group with 21–30 years of experience (1.03) and the 31–40-year group (0.84). The log estimate of the MSS score for workers with 40 or more years of experience was 1.07 over the referent group (less than 11 years of experience), which corresponds to a 2.91 increase in the MSS Score.

4. Discussion

The combined effects of logging systems, the workplace, and demographic factors have a role in MSS prevalence and the MSS score in the logging population studied. The years of experience, hours worked per week, and BMI were all included in models relating to the presence and severity (measured in MSS Score) of MSS in the Montana logging population. Workers involved in conventional chainsaw logging systems had an expected MSS score 1.29 points higher than workers in mechanized harvesting workers. When controlling for age, each decade of experience was associated with a different and significantly higher MSS score than workers with less than a decade of experience. Workers with the most logging experience had higher MSS scores as compared to the referent category; as a worker’s BMI increased outside the normal range, so did their likelihood of an increased MSS score.

While the mechanization of the logging industry has been associated with decreasing injuries [12,13,14], it is also associated with an increased productivity pressure and excessive shift lengths compared to CH [13]. The present study confirmed the finding that MH leads to more hours working in the forest. There were statistically significant increases in the hours worked per week and months worked per year for loggers using mechanized harvesting systems as opposed to conventional methods. Workers in mechanized harvesting systems worked, on average, eight hours more per week (48.6 hours in comparison to 40.0 hours) and almost one more month per year than workers using conventional methods (9.5 months in comparison to 8.8 months). The active logging season in Montana is predicated by environmental limitations not seen in other parts of the country. Loggers are unable to harvest in the summer months due to the high risk of forest fires (there are regulations on the use of internal combustion engines in the woods during periods of dry and hot weather). In addition, it is challenging to move mechanical harvesting equipment during the spring and fall months due to rain and unstable traction on muddy and soaked terrain. Therefore, the peak logging season is in the winter, after the roads and mud have frozen and the fire danger is gone. Due to the limitations discussed above, there is a slight variability in the season based on logging type. The use of CH operations may allow workers to harvest in the spring and fall seasons (as they are not subject to the transportation challenges); however, these operations experience limitations due to the bitter cold and snow in the winter season (when mechanized equipment with heated cabs are running). Significant associations have been reported for working in cold environments and the development of outdoor occupation injuries [24]. Unfortunately, working in extreme cold environments is a “reality” for forestry workers employed in mountainous regions.

Many researchers studying logging suggest that increasing the mechanization (by transitioning from CH to MH) should decrease the number of injuries and fatalities associated with logging [12,13,14]. In the present study, the authors found that workers in CH had a one-year period prevalence of MSS of 60%, while workers in MH had a one-year period prevalence of 50% and CH workers were over twice as likely to report MSS. However, the present study only considered the current employment, status and workers who are currently employed in mechanized systems may have changed jobs due to injury or the stressors of CH systems. This may correspond to elevated rates of MSS among loggers using mechanized equipment. In 1998, a study was conducted by Hagen, Magus, and Vetlesen to quantify MSS in Norwegian loggers [25]. In this study, a one-year period prevalence of MSS in the lower back was 24.8% among manual logging labors and 22.7% among logging equipment operators [25]. In comparison to the present study, the prevalence of lower back MSS in the Norwegian study population is quite low. However, the population demographics of the loggers in Norway were different from that of the population in the present study. MH workers in the Norwegian study had an average of 14 years of experience and manual workers had an average of 17 years of experience [25]. In contrast, the present study population had, on average, seven years more experience for mechanical operations and six years more experience in CH operations. The difference in the length of employment between these two populations could account for the differences in the prevalence of MSS.

While the prevalence of MSS in any body area was nonsignificant between loggers using conventional and mechanized harvesting systems, workers in MH had a higher prevalence of neck and upper back symptoms than workers in CH operations and workers using CH methods had a higher prevalence of MSS in every other body area. While the root cause of the ergonomic stressor varies between conventional and mechanized logging systems, both system types experience ergonomic hazards, which may result in injuries to various anatomical areas. Loggers in mechanized operations may experience symptoms in the neck and upper back due to constant head turning and twisting required to continually monitor the area outside the logging equipment [22,26]. Lewark, in 2005 in a systematic literature review, reported that loggers using MH equipment sustain low-level muscle actively for long hours with very little interruption. For this reason, Lewark concluded that organizational aspects must also be considered to address some of the emerging challenges from the transition to MH [4]. Workers in mechanized harvesting operations may experience MSS in the lower back due to vibration from sitting in the seat of the logging equipment [26] or may experience sprain/strain injuries in the lower back and lower extremity due to injuries incurred while climbing in and out of the equipment [14]. Zimmerman, Cook, and Rosecrance (1997) discovered a similar pattern of MSS in construction operating engineers which they attributed to prolonged and awkward postures, environmental conditions, noise, and whole-body vibration [27]. Both mechanized and conventional harvesting systems experience stressors in the hands and wrist. The use of a chainsaw is a well-documented risk for hand-arm vibration syndrome [13,14] and an increased association with carpal tunnel syndrome [28]. The persistent use of mechanized logging controls, however, has been associated with an increased incidence of repetitive strain injuries in the hands and arms [3,14]. Workers in CH also experience injury risks due to carrying heavy equipment, reaching, twisting, and walking over steep and varied terrain, which may be responsible for the increased prevalence of MSS in the lower extremities [14,23].

Due to similarities in risk and work activities, the U.S. National Institute for Occupational Safety and Health groups Agriculture, Forestry, and Fishing (AgFF) into a combined industry sector [29]. The AgFF sector has high rates of both fatal and nonfatal injury rates in comparison to the overall working population and other industry sectors [29]. As a sector, AgFF had an occupational fatality rate of 25.6 per 100,000 FTE, while the average across all industries was 3.4 per 100,000 FTE [29]. Some of the unique risks to the AgFF sector which are shared between farmers and loggers include outdoor work in harsh conditions, rural work locations, low profit margins, and seasonal variation [29]. In addition, both of these industries require heavy and dangerous equipment, repetitive motions, and awkward postures [29]. Forestry and farming vary in the season of work, the specific types of machinery and equipment, as well as the degree of automation and mechanization. The MSS prevalence reported in Montana loggers as a result of this study was similar to the MSS prevalence found in a population of Kansas farmers by Rosecrance, Rodgers, and Merlino (2006). The one-year period prevalence of low back pain in the farming population was reported to be 38% [30]. The MSS prevalence was reported by anatomical region in the shoulders (26%), knees (24%), and neck regions (22%) [30]. This corresponds closely with the prevalence found in the Montana logging population, where the MSS prevalence was 38% in the low back, 28% in the shoulders, 25% in the knees, and 25% in the neck. The mean age of Kansas farmers was 58 years, the mean BMI was 28, and the mean duration employed a farmer was 36 years. In comparison, the mean age of the Montana loggers in this study was 46 years, the mean BMI was 28, and the mean duration as a logger was 22 years. While the one-year period prevalence of MSS in these populations is nearly identical, the mean age and the duration of employment varies by over a decade. The comparison between logging and farming workers is interesting due to similarities in the work tasks and culture between these two industries. The demographic differences between these two populations, paired with a similarity of the MSS survey results, demonstrates that loggers are experiencing the same symptom prevalence at younger ages and after a fewer years working in their industry than farmers.

4.1. Limitations

There are several limitations in the current study design. The population used for the study was limited to loggers participating in a safety-training event in Montana. There is a possible selection bias due to the lack of information collected from nonrespondents. Due to the potential bias, we cannot be sure we obtained a representative sample from the population attending the safety training course. Additionally, the symptom prevalence rate may have been influenced by the lower-than-ideal response rate (>80%) as noted by Dickinson et al. (1992) [31]. Due to industry differences across the nation and around the world, the authors cannot be certain that this population and the subsequent results can be generalized to the logging industry across the region or the country. In addition, to obtain information on the logging system type and job type, the researchers asked for participants to report their current (in the last year) job and logging system type and did not obtain information on the job type and logging system used in previous years. This may bias the results toward the null when comparing conventional and mechanical operations, as workers who are currently employed in mechanized systems may have changed jobs due to injury or the stressors of CH.

Due to the retrospective nature of the survey instrument, the investigators relied on respondents' recall of past events to accurately complete the workplace factors and MSS questionnaire. Rosecrance et al. developed the modified version of the SNQ used in this study to quantify the severity of MSS rather than the duration or start MSS, which reduced the impact of recall bias. Instead of asking if MSS occurred over the worker's entire life, the last year, or the last week, this study quantified the severity of MSS by asking if the worker had "experienced job-related symptoms", "been prevented from doing a day's work", or "seen a physician". Rosecrance et al. found lower kappa coefficients (a measure of test-retest reliability which accounts for an agreement due to chance) (κ = 0.13–071) during a reliability analysis for questions related to whether the workers experienced job-related symptoms in a particular body area and higher kappa coefficients (κ = 0.48–0.82) for the questions in regard to the worker seeing a physician in the last year for MSS localized to a worker's particular body area [32]. The authors' reason that the difference between the reliability measures of these two questions is due to "respondent's better recall of actual events such as traveling to the physician's office versus the recall of subjective symptoms in the preceding 12 months" [32].

4.2. Practical Recommendations

As a result of the present study, the authors worked with the Montana Logging Association to develop intervention strategies to reduce the rates of MSS, injuries, and deaths related among professional (and nonprofessional) forestry loggers in Montana. One of the primary safety recommendations was to continue to support the transition of conventional to mechanized logging systems in Montana. This recommendation included not only the use of feller-bunchers for felling trees but also other heavy equipment for processing and skidding logs. With increases in heavy equipment use, knee and ankle sprains were a hazard related to operators falling and jumping from heavy equipment. Thus, to reduce this risk, the Montana Logging Association developed signage to identify these hazards and to attach to logging equipment. The signage was then distributed to logging companies for use on their equipment. Educational programs related to the MSS risks identified in this and other studies were developed for professional loggers and integrated into their annual safety training. Because of the increasing use of heavy equipment in mechanized logging, video training modules were also developed on the safe use of logging equipment. Due to the high cost of logging equipment, logging simulators were also purchased by the Association to train new workers on equipment controls before actual field training. To meet some of the safety needs of nonprofessional loggers, the authors collaborated with the Montana Forestry Extension Specialists to produce a series of online videos regarding safe chainsaw operating procedures.

5. Conclusions

Quantifying the current symptom prevalence in the logging population can help identify possible areas and opportunities for interventions, as well as measure the success of interventions after implementation. Researchers have demonstrated a significant association between the level of reported MSS and the development of injuries in the future [33]. Therefore, the information collected in this study can be used to assess the potential development of injuries of logging workers.

Other authors have indicated that mechanization is successful in reducing injury occurrence; however, in the Montana population, workers using mechanized systems are still experiencing high levels of MSS. Using regression models, conventional harvesting systems can be attributed to the increased prevalence of MSS and the higher MSS scores among loggers; however, other workplace factors, such as BMI and experience, also have a significant effect.

While emerging advancements in harvesting techniques, such as steep-slope harvesting, may have application in Montana, the prevalence of musculoskeletal symptoms in workers using mechanized logging systems was still 50%. Therefore, moving forward, injury prevention efforts in the logging industry should continue to focus on engineering and administrative controls to decrease the occurrence of MSS, injuries, and deaths among professional loggers using both mechanical and conventional harvesting systems. Additional logging research must also consider the safety culture, safety leadership, and the link between safety management systems and operational excellence as additional methods to improve safe work practices in forestry logging.

Acknowledgments

The authors are deeply grateful for the cooperation and partnership that has been formed with the Montana Logging Association. This research would not have been possible without the synergetic collaboration between industry and academia. We hope that this research will lead to interventions that will benefit the loggers who work tirelessly to provide for their families and to meet the nation's demand for this resource.

Funding

This research was supported in part by the National Institute for Occupational Safety and Health (NIOSH) Mountain and Plains Education and Research Center, grant number 5T42OH009229, and the NIOSH-funded High Plains Intermountain Center for Agricultural Health and Safety, grant number U54 OH008085. The content is the responsibility of the authors and does not necessarily represent the official views of the NIOSH.

References

1. Garland JJ Accident reporting and analysis in forestry: Guidance on increasing the safety of forest work. In Proceedings of the Forest Engineering Conference, Rotorua, New Zealand, 17 April 2018.
2. Gallis C Work-related prevalence of musculoskeletal symptoms among greek forest workers. Int. J. Ind. Ergon. 2006, 36, 731–736.
3. Axelsson S-Å; Pontén B New ergonomic problems in mechanized logging operations. Int. J. Ind. Ergon. 1990, 5, 267–273.
4. Lewark S Scientific Reviews of Ergonomic Situation in Mechanized Forest Operations- Introducing the Five Reviews of The Ergowood Project; Institutionen för skogens produkter och marknader: Freiburg, Germany, 2005.

5. United States Department of Labor, O.S.H.A. Safety and health topics: Logging. Available online: https://www.osha.gov/SLTC/logging/ (accessed on 3 March 2019).
6. Bureau of Labor Statistics. Logging workers had highest rate of fatal work injuries in 2015. Available online: https://www.bls.gov/opub/ted/2017/logging-workers-had-highest-rate-of-fatal-work-injuries-in-2015.htm (accessed on 3 March 2019).
7. United States Bureau of Labor Statistics. Industry injury and illness data- 2015. U.S. Bureau of Labor Statistics, Ed.; 2017. Available online: https://www.bls.gov/iif/oshsum.htm#15Summary_Tables (accessed on 3 March 2019).
8. Tsioras PA; Rottensteiner C; Stampfer K Wood harvesting accidents in the austrian state forest enterprise 2000–2009. Saf. Sci. 2014, 62, 400–408.
9. Taylor Moore J; Cigularov KP; Sampson JM; Rosecrance JC; Chen PY Construction workers' reasons for not reporting work-related injuries: An exploratory study. Int. J. Occup. Saf. Ergon. 2013, 19, 97–105. [PubMed: 23498712]
10. Evanson T; Bentley T; Parker R; Ashby L; Tappin D Reported near-miss incidents-1995 to 1999: An exploratory analysis of new zealand logging industry near-miss-data. Report 2001, 2, 1–12.
11. Montana Logging Association. Logging systems. Available online: http://logging.org/healthy_forests/logging_systems.php (accessed on 1 September 2016).
12. Bordas RM; Davis GA; Hopkins BL; Thomas RE; Rummer RB Documentation of hazards and safety perceptions for mechanized logging operations in east central alabama. J. Agr.Saf. Health 2001, 7, 113–123. [PubMed: 11465386]
13. Nieuwenhuis M; Lyons M Health and safety issues and perceptions of forest harvesting contractors in ireland. J. For. Eng. 2002, 22
14. Axelsson S-Å The mechanization of logging operations in sweden and its effect on occupational safety and health. J. For. Eng. 1998, 9, 25–31.
15. Lagerstrom E; Magzamen S; Rosecrance J A mixed-methods analysis of logging injuries in montana and idaho. American J. Ind. Med. 2017, 60, 1077–1087.
16. Smith DW Chainsaw safety. Available online: http://agrilife.org/agsafety/files/2011/06/CHAINSAW-SAFETY2.pdf (accessed on 3 September 2019).
17. Bell JL Changes in logging injury rates associated with use of feller-bunchers in west virginia. J. Saf. Res. 2002, 33, 463–471.
18. Kuorinka I; Jonsson B; Kilbom A; Vinterberg H; Biering-Sorensen F; Andersson G; Jorgensen K Standardised nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. 1987, 18, 233–237. [PubMed: 15676628]
19. Crawford JO The nordic musculoskeletal questionnaire. Occup. Med. 2007, 57, 300–301.
20. National Institutes of Health. Assessing your weight and health risk. Available online: https://www.nhlbi.nih.gov/health/educational/lose_wt/risk.htm#limitations (accessed on 3 March 2019).
21. SAS, version 9.4; SAS Institute Inc.: Carrey, NC, USA, 2012.
22. Schettino S; Campos JCC; Minette LJ; Souza A.P.d. Work precariousness: Ergonomic risks to operators of machines adapted for forest harvesting. Revista Árvore 2017, 41, 1–9.
23. Harstela P Work postures and strain of workers in nordic forest work: A selective review. Int. J. Ind. Ergon. 1990, 5, 219–226.
24. Morabito M; Iannuccilli M; Crisci A; Capecchi V; Baldasseroni A; Orlandini S; Gensini GF Air temperature exposure and outdoor occupational injuries: A significant cold effect in central italy. Occup. Environ. Med. 2014, 71, 713–716. [PubMed: 25080542]
25. Hagen KB; Magnus PER; Vetlesen K Neck/shoulder and low-back disorders in the forestry industry: Relationship to work tasks and perceived psychosocial job stress. Ergonomics 1998, 41, 1510–1518. [PubMed: 9802255]
26. Lynch SM; Smidt M; Merrill PD; Sesek RF Incidence of msds and neck and back pain among logging machine operators in the southern U.S. J. Agric. Saf. Health 2014, 20, 211–218. [PubMed: 25174152]
27. Zimmermann CL; Cook TM; Rosecrance JC Operating engineers: Work-related musculoskeletal disorders and the trade. Appl. Occup. Environ. Hyg. 1997, 12, 670–680.

28. Bovenzi M; Zadini A; Franzinelli A; Borgogni F Occupational musculoskeletal disorders in the neck and upper limbs of forestry workers exposed to hand-arm vibration. Ergonomics 1991, 34, 547–562. [PubMed: 1653132]
29. National Institute for Occupational Safety and Health. Agricutlure, forestry and fishing. Available online: https://www.cdc.gov/niosh/programs/agff/bni.html (accessed on 3 March 2019).
30. Rosecrance J; Rodgers G; Merlino L Low back pain and musculoskeletal symptoms among kansas farmers. American J. Ind. Med. 2006, 49, 547–556.
31. Dickinson C; Campion K; Foster A; Newman S; O'rourke A; Thomas P Questionnaire development: An examination of the nordic musculoskeletal questionnaire. Appl. Ergon. 1992, 23, 197–201. [PubMed: 15676868]
32. Rosecrance JC; Ketchen KJ; Merlino LA; Anton DC; Cook TM Test-retest reliability of a self-administered musculoskeletal symptoms and job factors questionnaire used in ergonomics research. Appl. Occup. Environ. Hyg. 2002, 17, 613–621. [PubMed: 12216590]
33. Nordlund A; Ekberg K Self reported musculoskeletal symptoms in the neck/shoulders and/or arms and general health (sf-36): Eight year follow up of a case-control study. Occup. Environ. Med. 2004, 61, e11. [PubMed: 14985528]

Figure 1.

The primary logging systems for felling trees: (**a**) conventional chainsaw felling and (**b**) heavy mechanical equipment felling using a feller-buncher.

Table 1.

The respondent demographics.

Respondent Demographic	Mean (SD); n = 743
Age	45.9 (13.7)
Body Mass Indices (BMI)	28.4 (4.8)
Years working in Logging Industry	22.0 (14.1)
Hours Worked Per Week in Logging	47.1 (15.5)
Months Worked Per Year in Logging	9.3 (2.6)
Gender	n (Percent)
Male	701 (94.3%)
Female	21 (2.8%)
Missing	21 (2.8%)
Ethnicity	
Caucasian	664 (89.4%)
Other	33 (4.4%)
Missing	46 (6.2%)
First Language	
English	681 (91.7%)
Spanish	2 (0.3%)
Missing	60 (8.1%)
Highest Education Level Achieved	
Did not finish High School	55 (7.4%)
High School Diploma	410 (55.2%)
Some College	179 (24.1%)
Bachelor’s Degree or Higher	59 (7.9%)
Missing	40 (5.4%)
Primary Logging System Type	
Conventional	80 (10.8%)
Mechanical	408 (54.9%)
Both	28 (3.8%)
Missing (includes truck drivers)	227 (30.6%)

Table 2.

The demographics by logging system type.

Demographic/Workplace Factor	Conventional Harvesting Methods (n = 80) Mean (SD)	Mechanized Harvesting Methods (n = 408) Mean (SD)
Age	44.9 (14.0)	44.2 (13.1)
BMI	27.7 (4.0)	28.6 (4.8)
Years in Logging Industry	23.1 (14.1)	21.9 (13.6)
Hours Worked Per Week in Logging	40.0 (12.7) *	48.6 (13.4) *
Months Worked Per Year in Logging	8.8 (2.6) *	9.5 (2.1) *

*Indicates significance $p < 0.05$.

Table 3.

The percentage of workers reporting musculoskeletal symptoms (one-year period prevalence): conventional vs. mechanical operations.

Anatomical Location of MSS	All Responses	Conventional (n = 80)	Mechanical (n = 408)
Neck	24.8%	19.1%	27.0%
Upper Back	17.8%	17.5%	18.9%
Lower Back	38.1%	45.5%	39.4%
Shoulders	27.6%	34.9%	25.9%
Elbows	14.5%	17.7%	14.5%
Wrist/Hands	21.0%	27.4%	21.5%
Hip/Thighs	17.1%	21.9%	16.2%
Knees	24.7%	33.8%	25.8%
Feet	13.8%	20.6%	12.2%
Symptoms in any area	48.1%	59.7%	49.6%
Missed work due to symptoms in any area	6.0%	9.7%	6.3%
Musculoskeletal disorder symptoms (MSS) Score (Mean Number of MSS Categories Reported)	1.8	2.1	1.8

[+]The overall category includes all respondents to the MSS questionnaire (including truck drivers and workers in mixed logging systems).

Table 4.

The regression results: indicators of MSS in Montana loggers (the bolded values indicate a statistical significance).

Workplace Factor	MSS in any Anatomical Area (Y/N) Odds Ratio (95% CI)	Missed Work due to MSS (Y/N) Odds Ratio (95% CI)	MSS Score (0–9 Scale) Estimate (95% CI)
Primary Logging System			
Conventional	**2.24 (1.07–4.69)**	3.37 (0.96–11.80)	**0.26 (0.34–1.15)**
Mechanical	1.0 (referent)	1.0 (referent)	0.0 (referent)
Age	0.98 (0.95–1.02)	0.93 (0.86–1.01)	−0.01 (−0.023–0.00)
BMI			
Normal (18.5–24.9 kg/m)	1.0 (referent)	1.0 (referent)	0.0 (referent)
Overweight (25.0–29.9) kg/m	0.71 (0.36–1.42)	0.75 (0.20–2.79)	**−0.39 (−0.60– −0.19)**
Obese (>29.9 kg/m)	0.81 (0.39–1.70)	1.12 (0.67–4.669)	**−0.35 (−0.57– −0.13)**
Years of Experience in Logging			
0–10	1.0 (referent)	1.0 (referent)	0.0 (referent)
11–20	2.14 (0.98–4.70)	1.30 (0.27–6.10)	**0.48 (0.20–0.76)**
21–30	**3.85 (1.51–9.79)**	1.92 (0.26–14.12)	**1.03 (0.71–1.35)**
31–40	**3.55 (1.09–11.55)**	1.43 (0.08–24.46)	**0.84 (0.44–1.24)**
40+	4.44 (0.96–20.25)	8.11 (0.42–157.15)	**1.07 (0.57–1.57)**
Hours Worked Per Week			
0–39	0.68 (0.23–1.96)	-	−0.23 (−0.60–0.14)
40–60	1.0 (referent)	1.0 (referent)	0.0 (referent)
60+	0.90 (0.33–2.44)	0.70 (0.08–5.94)	−0.18 (−0.52–0.15)
Months Worked Per Year			
Less than 9	1.53 (0.76–3.11)	0.27 (0.03–2.27)	0.19 (−0.02–0.41)
9–12 (Full Season)	1.0 (referent)	1.0 (referent)	0.0 (referent)