EasyChair Preprint

№ 5940

A Wearable Device to Assess the Spine Biomechanical Overload in a Sample of Loggers

Federica Masci, Giovanna Spatari, Concetto Mario Giorgianni, Sara Bortolotti, John Rosecrance and Claudio Colosio

June 27, 2021

“A wearable device to assess the spine biomechanical overload in a sample of loggers”

F Masci[1], G. Spatari[2], C.M. Giorgianni[2], S. Bortolotti[3], J. Rosecrance[4], C. Colosio1[1]

[1] Department of Health Sciences of University of Milan and International Centre for Rural Health of the Santi Paolo e Carlo ASST of Milan – Milano, Italy
[2] Department of Biomedical, Dental and Morphological and Functional Imaging - University of Messina – Messina, Italy
[3] University of Milan – Milano, Italy
[4] Department of Environmental and Radiological Health Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO, USA

Federica.masci@unimi.it

Abstract Forestry workers are exposed to harsh environmental conditions, awkward postures, and high intensity load handling that might lead to low back injuries. The objectives of our study were 1) to define the trunk postures associated with risk of low back injury in a sample of forestry workers involved in tree felling, delimbing and bucking tasks and 2) to identify prevention strategies that reduce the risk of low back injury. Forty loggers were selected among the population of forestry workers in the province of Enna, Sicily-Italy. Each worker was required to perform for a period of 30 minutes the three main tasks: felling, delimbing and bucking for a total of 90 minutes of working activity. All subjects involved in the study wore a Zephyr Bioharness device on their trunk, which enabled the recording of sagittal inclination of the trunk, heart rate, breathing rate, and an estimate of body temperature. The results indicated that the felling task required loggers to work more time in awkward postures. Additionally, sagittal inclination of the trunk was greater than 60° for the 13% of the time, compared with delimbing (3%), and bucking (11%). The percentage of time spent with the trunk in sagittal inclination greater than 60° was correlated with the use of heavy (> 7,2 kg) chainsaws during the felling and in the delimbing tasks. The study results indicated that the trunk posture during tree delimbing and felling tasks contributed significantly to the risk of biomechanical overload among the loggers. Preventive strategies should focus on specific interventions that reduce biomechanical stress including worker training and implementation of ergonomic designed tool.

KEYWORDS: Biomechanical overload, spine, loggers.

1 Introduction

According to official statistics from the Eurostat Labour Force Survey, musculoskeletal disorders (MSDs) are currently the most prevalent work-related diseases in

Europe (1). The primary reported clinical outcomes are back pain/injuries and work-related upper limb disorders, followed by lower limbs diseases. Recent studies provide substantial evidence that heavy loads lifting, awkward and prolonged posture, repetitive movements and lack of pauses are among the causes of these disorders, that also represent one of the most important reason of long-term sickness absences (2).

In Italy, the incidence of MSDs has systematically grown across all industries and especially in forestry sector, where low back injuries are reported to be the 60% of the total occupational diseases claimed to the Italian compensation authority(INAIL), in the period between 1999-2012. (3) In particular, among the Italian regions, Sicily have registered in the same period a percentage of 35% of low back occupational disease among forestry workers (4).

The literature indicates that combined exposure to vibration, biomechanical overload and awkward postures is mainly characteristic of many tasks performed in silviculture (5). Moreover, high intensity work rhythm and lack of training may increase the incidence of musculoskeletal diseases in forestry workers required to carry heavy loads for a long period (6). Spasms, muscular pain and sleep diseases are among the most common disorders workers refer about (7), that also contribute to accidents or near miss.

Studies have also shown that felling, delimbing and bucking tasks (Figures 1, 2 and 3 respectively) require a considerable effort, which increases with hardwood harvesting. (8)

Figure 1: Tree felling task

Figure 2: Tree delimbing task

Figure 3: Tree bucking task

In order to evaluate the biomechanical overload, different methods such as OWAS (9), RULA, RIBA (10)and OCRA (11) were successfully used in the forestry industry. Nevertheless, there are few original studies in literature that quantify low back biomechanical overload among forestry workers using a wearable technology.

Assessing the risk of spine injuries among forestry workers is the first step in the development of prevention strategies. Therefore, the aim of our study was to a) determine the trunk postures associated with risk of low back injury in a sample of forestry workers involved in tree felling, delimbing and bucking tasks; b) investigate the strength of correlations between biomechanical risk and personal as well as chainsaw characteristics; and c) identify prevention strategies to reduce the risk of low back injury.

2 Material and Methods

Forty male loggers were selected among the population of forestry workers in the province of Enna (Sicily), Italy. Participant study selection criteria were least eighteen years old, but not older than 65 and to have at list three years of working experience in logging activities. All the workers involved in the study were informed about the aims of the research and signed informed consent.

Each worker was required to perform the tasks of felling, delimbing and bucking for a period of 30 minutes each. All subjects wore a Zephyr Bioharness (Figure 4) around their chest to detect and store the following information: sagittal inclination of the trunk, activity level (static, walking, running), heart rate, breathing rate and estimated body temperature.

Figure 4: A worker equipped with Zephyr Bioharness 3

Before the data collection in the field, each worker was asked to stand straight next to a wall for 30 seconds in order to normalize the individual's natural anatomical inclination of the trunk to their upright posture.

Trunk posture data were processed after the data collection and were classified in 4 angle inclination:

- < 0°
- 0° - 30°
- 30° - 60°

- > 60°

Based on this criterion, the percentage of time spent in the different posture was calculated.

Besides, also personal data (age, working experience, secondary job), anthropometric measurements (height and weight) and the characteristics (model and weight) of the chainsaws the loggers were using during the task performance were collected.

The average weight of the chainsaw (about 7.39 kg.) was used as cutoff to classify them as "light" or "heavy".

2.1 Statistical Analysis

Data processing and statistical analyses were performed using the program SPSS PC version 23. The differences among the tasks and trunk inclination of the workers were investigated using a repeated measures ANOVA, with statistical significance set at $p \leq 0.05$. We also investigated the role of the personal variables (age, BMI and working experience) in the performance of the different tasks and trunk inclination using an ANOVA, with statistical significance set at $p \leq 0.05$.

3 Results

3.1 Study Population

The study involved a sample of 40 male chainsaw operators recruited from the population of forestry workers in the province of Enna (Sicily). Anthropometric measurements (height and weight) and personal data (age, sport, working experience, secondary job) were collected and are shown in table 1.

Table 1: Characteristics of the population

	Min	Max	Mean	SD
Height (cm)	152	187	172,00	7,582
Weight (kg)	60	110	81,95	13,814
Age (years)	47	63	52,60	4,534
Body Mass Index	21,2	35,9	27,6	3,7
Working experience (years)	6	41	27	6

The average age of the workers recruited to the study was 53 years, with a minimum age of 47 and a maximum age of 63 (D.S. 4.53). As shown in table 1, average height was 172 cm with a minimum of 152 cm and a maximum high of 187 cm (D.S. 7.852); the average weight was about 82 kg with a minimum of 60 kg and a maximum of 110 (D.S. 13.814). From these data we obtained the Body Mass Index (BMI). The average BMI was 27.61. Fourteen workers were normal weight, 16 overweight, 9 suffer from mild obesity and 1 of medium obesity. The sample recruited had an average of 27 years of work experience, with a minimum of 6 years and a maximum of

41. Only three persons declared to perform sports: football, trekking and volleyball respectively. The sport variable was therefore not considered in the analyses.

Out of 40 workers, 13 declared they did not perform any secondary job, 15 declared they were employed in other agriculture activities, 9 in the construction sector and 3 in food market (2) and transport sectors (1). The minimum weight of the chainsaws used by the workers was about 3.1 kg, while the maximum was 8.3 kg. Therefore, average weight of the chainsaws (about 7.39 kg.) was used as cut off to define a heavy or light chainsaw. In particular, most workers (n = 31) used a "heavy" chainsaw, while only 9 workers used "light" chainsaws.

3.2 Trunk inclination

Our results indicated that the forestry workers spent approximately the same proportion of time (18%) in sagittal trunk inclination less than 0° in the three tasks (Figure 5). Moreover, the felling task required loggers to work more time in awkward postures: the sagittal inclination of the trunk resulted greater than 60° for the 13% of the data collection time, compared with delimbing (3%), and bucking (11%). (Figure 6).

Figure 5: Percentage of time spent with a sagittal inclination of the trunk less than 0° during felling, bucking and delimbing

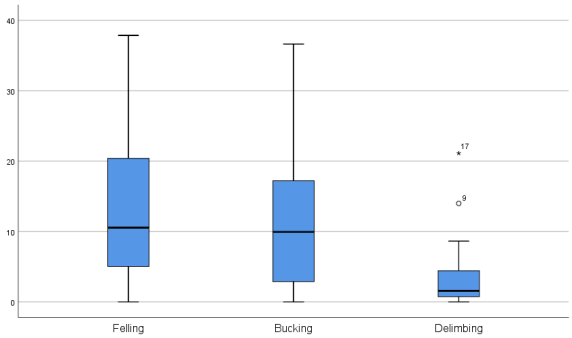

Figure 6: Percentage of time spent with a sagittal inclination of the trunk greater than 60° during felling, bucking and delimbing

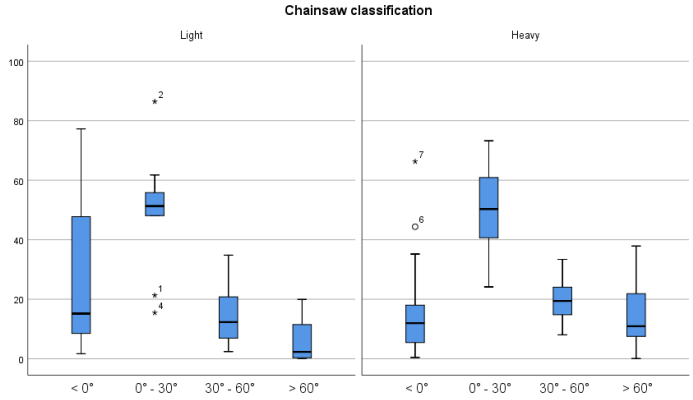

Figure 7: Comparison among the percentage of time spent with a sagittal inclination of the trunk respectively less than 0°, 0° - 30°, 30° - 60° and greater than 60° and chainsaw's weight used during the felling task (P < 0,05).

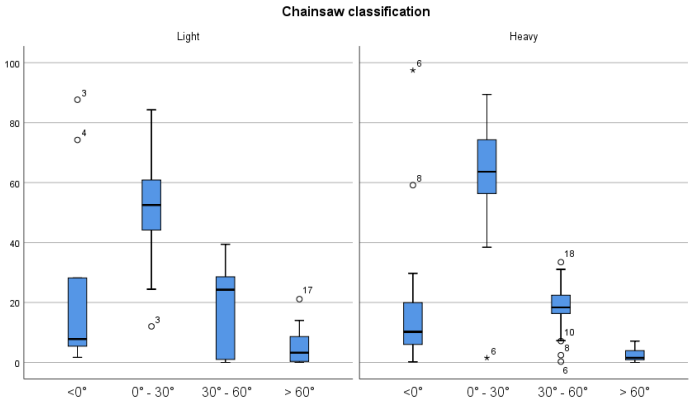

Figure 8: Comparison among the percentage of time spent with a sagittal inclination of the trunk respectively less than 0°, 0° - 30°, 30° - 60° and greater than 60° and chainsaw's weight used during the delimbing task(P < 0,05).

In the felling (Figure 7) and in the delimbing tasks (Figure 8) the percentage of time spent with a sagittal inclination of the trunk greater than 60° is correlated with the use of heavy chainsaws (> 7,2 kg).

No statistically significant differences were found among the working posture in the 3 tasks in relation to age, BMI and working experience and secondary job.

4 Discussion and conclusions

The Zephyr BioHarness 3 device was used to assess the trunk inclination in a sample of loggers while performing the tasks of trees felling, delimbing and bucking. The results of the data analysis assisted in the development of prevention strategies to mitigate the risk of low back disorders among forestry workers in the region of Sicily. Our results suggest the felling trees is a high-risk task for low back injuries, which requires workers to spend a high percentage of time with a trunk inclination greater than 60 °.

These findings are consistent with Grzywinski et al. who analyzed 10 expert chainsaw operators and noted that using a chainsaw requires a great effort to the musculoskeletal system especially during the felling phase, where the condition of bent legs and back are very common (12). Moreover, Sawastian (13) assessed the awkward postures of two loggers using different chainsaws with the OWAS (Ovako Working Posture Analysis System) method. Sawastian (12) reported that the loggers postures were in the high risk category of the OWAS system. Unfortunately, occupational exposure to such awkward postures and repetitive motions are primarily related to low back pain (LBP) (14), especially if performed wearing wet clothes in harsh environment (15).

Our study also tried to investigate if personal factors such as age and BMI could affect awkward postures. Interestingly, no differences were found comparing the data of older workers (> 55 years) to the youngest. Conversely, we noted in the present study, that during the felling task, those suffering from mild obesity spent more time with an inclination of the trunk between 30 ° and 60 ° compared to normal weight workers, which spend most of their time in appropriate trunk postures. Nevertheless, this difference was not statistically significant.

Miranda (date) conducted a study of 7000 employees in a large forestry industry in Finland that completed a questionnaire related to musculoskeletal pain and potential risk factors, such as age, sex, BMI, sport and mental stress. The study demonstrated that the risk of shoulder pain increased with both age and body mass index and the awkward sagittal inclination(>60°) represent an additional risk factor (16). Interestingly Miranda also noted that dancing slightly increases the risk of shoulder pain, while running decreases the risk (16). Unfortunately, we couldn't explore the correlation of our results to sport, since only few workers declared to play sport.

Lastly the study results indicated that the trunk posture during tree delimbing and felling tasks contributed significantly to the risk of biomechanical overload among the loggers in association to heavy chainsaw. A study supporting this finding indicated that working postures that involve trunk flexion during felling task with chainsaw may lead to increased loading of the lumbar paraspinal muscles, suggesting a relationship between low back pain and the use of a chainsaw (17).

The Zephyr Bioharness demonstrated to be a useful wearable exposure assessment tool to characterize the postures associated with biomechanical overload in the low

back among forestry workers. Safety training initiatives have been successful in reducing injuries and increasing workers' awareness of health and safety issues among loggers (18). Additionally, others have reported that if adequate work training is associated to a good working environment, which includes safety tools, the physical workload decreases and productivity improves (19). Strategies to prevent biomechanical overload in the trunk of loggers should focus on specific interventions such as worker training in order to promote the adoption of proper postures and implementation of ergonomic designed tools.

Acknowledgments

The authors want to thank the forestry department of the province of Enna, the Health and Safety manager and the Occupational Physician of the company who helped in the study population selection.

References

1. EUROSTAT. Exposure to risk factors. Health and safety at work in Europe (1999-2007). 2010. 103 p.
2. European Agency for Safety and Health at Work - Annual Report 2017 Luxembourg: Publications Office of the European, 2018 Print ISBN 978-92-9496-815-9 ISSN 1681-0155 doi: 10.2802/680079.
3. Rapporto Inail Infortuni e malattie professionali 1 Luglio 2012.
4. INAIL. MALPROF 2011-2012- Rapporto INAIL_Nessi causali positivi Malattie del rachide. 2016.
5. Blombäck P. Improving occupational safety and health: the International Labour Organization's contribution FAO. 2002.
6. Lewark S. Institutionen för skogens produkter och marknader Scientific reviews of ergonomic situation in mechanized forest operations Siegfried Lewark, ed. 2005;(2).
7. Ashby L, Bentley T, Parker R. Musculoskeletal disorders in silviculture and logging 1995 – 1999. OHFE. 2001;
8. Blombäck P, Poschen P, Lövgren M. Employment Trends and Prospects in the European Forest Sector 2003 Geneva Timber and Forest Discussion Papers. United Nations.
9. A. C. Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems" Musculoskeletal disorders (MSD) risks in forestry: a case study to propose an analysis method. DEIAFA, Italy. 2008;
10. Micheletti Cremasco M, Giustetto A, Caffaro F, Colantoni A, Cavallo E, Grigolato S. Risk Assessment for Musculoskeletal Disorders in Forestry: A Comparison between RULA and REBA in the Manual Feeding of a Wood-Chipper. Int J Environ Res Public Health [Internet]. 2019;16(5). Available from: http://www.ncbi.nlm.nih.gov/pubmed/30841494
11. Jones T, Kumar S. Comparison of ergonomic risk assessment output in four sawmill jobs. Int J Occup Saf Ergon. 2010;16(1):105–11.

12. Grzywiński W, Jelonek T, Tomczak A, Jakubowski M, Bembenek M. Does body posture during tree felling influence the physiological load of a chainsaw operator? Ann Agric Environ Med. 2017;24(3):401–5.
13. Sawastian K, Grzywiński W, Turowski R. Analysis of postural strain of loggers during timber harvesting in a spruce stand Analysis of postural strain of loggers during timber harvesting in a spruce stand. 2016;(January 2015).
14. Petit A, Roquelaure Y. Low back pain, intervertebral disc and occupational diseases. Int J Occup Saf Ergon [Internet]. 2015;21(1):15–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26327258
15. Skandfer M, Talykova L, Brenn T, Nilsson T, Vaktskjold A. Low back pain among mineworkers in relation to driving, cold environment and ergonomics. Ergonomics [Internet]. 2014 Oct 3;57(10):1541–8. Available from: http://www.tandfonline.com/doi/abs/10.1080/00140139.2014.904005
16. Miranda H, Martikainen R, Takala E, Riihimäki H. <Miranda-2001-A prospective study.pdf>. 2001;528–34.
17. Kawahara D, Urabe Y, Maeda N, Sasadai J, Fujii E, Moriyama N, et al. [The effect of different working postures while felling a tree with a chain-saw on trunk muscles' activity]. Sangyo Eiseigaku Zasshi [Internet]. 2015;57(4):111–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25995000
18. Nkomo H, Niranjan I, Reddy P. Effectiveness of Health and Safety Training in Reducing Occupational Injuries Among Harvesting Forestry Contractors in KwaZulu-Natal. Workplace Health Saf [Internet]. 2018 Oct;66(10):499–507. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29962302
19. Erhan Caliskan e Sadik Caglar. An assessment of physiological workload of forest workers in felling operations. African J Biotechnol. 2010;9 (35):5651–8.