Musculoskeletal Disorders (MSD) Risks in Forestry. A Case Study to Suggest an Ergonomic Analysis

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ABSTRACT

Musculoskeletal disorders (MSDs) are amongst the most common work-related problem in Europe. In forestry yards we find all the conditions which expose workers to MSD risks: hard environmental conditions (low temperatures, slippery and uneven ground), heavy works (manual handling of loads, back flexed and twisted) and dangerous tools and machineries such as chainsaws. The high manual work load can therefore cause MSDs amongst the loggers. This pathology risk increases with the component 'vibration' induced by chainsaws, tractors, skidders and other machineries. In this study we have considered two different logger groups working in public forestry yards and we have analyzed their MSD risk exposure, controlling both the posture of each worker and measuring the induced vibration on the hand-arm system and on the back. The OWAS (Ovako Working-posture Analysis System) technique has been used to evaluate the load MSD risk and the 2002/44/EC Vibration Directive has been used to detect the exposure to vibration. In the first loggers group, mechanical trees felling (using chainsaw) and manual deforestation were the performed tasks; in the second, the operations were mechanical trees felling and log stacking (using also a tractor). The work of eight loggers was analyzed, evaluating all risk types. The result was that both the OWAS index and the vibration indicators were quite high. But others risk parameters came out that are not included in the OWAS or in the 2002/44 EC directive methodology: for example, the work related neck and upper limb disorders, which may be detected using the OCRA procedure in the case of driving powerful forestry machines.

Keywords: OWAS, WRULD, Forestry, MSD, Vibration

1. INTRODUCTION

Musculoskeletal disorders (MSD) are common work-related problems in Europe. Almost 24% of all the European workers report suffering from backache and 22% complain about muscular pains. Moreover, almost 2/3 of workers in Europe report being exposed to repetitive hand-arm movements and ¼ to vibrations: these are significant risk factors for developing WRULD (Work Related neck and Upper Limb Disorders) (European Agency, 2008). Most work-related MSD and WRULD are cumulative disorders, resulting from repeated exposure to high or low intensity loads, from repetitive movements and from vibrating tools utilization over a long period of time: however, MSD and WRULD can also be acute traumas, such as fractures, that occur during an accident. Different groups of factors may contribute to develop these pathologies, including physical or biomechanical factors and organisational and psychosocial factors (Waters, 2004). From the analysis of the INAIL (Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro, translated into Nation Institute for Insurance against Industrial Injuries) data in Italy during the period 2002-2006, it emerges that professional illness related to the MSD are increasing (figure 1).

In forestry yards we find all the conditions which expose workers to MSD risks: hard environmental conditions (low temperatures, slippery and uneven ground), heavy works (manual handling of loads, back flexed and twisted) and dangerous tools and machineries such as chainsaws. The high manual work load can therefore cause MSDs amongst the loggers (Ashby *et al.*, 2001).

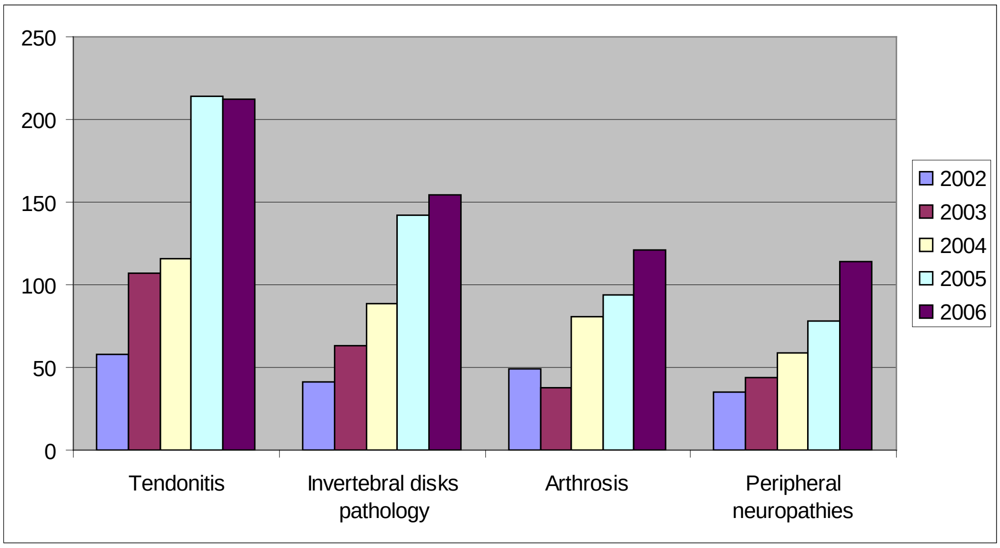

Figure 1. Professional MSD related illness reported in Italy in the period 2002-2006 (INAIL data).

This pathology risk increases with the component 'vibration' induced by chainsaws, tractors, skidders, harvester and other machineries (Bovenzi, 2003). In fact, both the WBV (Whole Body Vibration) and the HAV (Hand Arm Vibration) have been detected as important risk factors which may cause MSDs and they must be strictly controlled. Engineering solutions to reduce WBV and HAV levels experienced by agricultural vehicle operators are commonplace, historically in the guise of spring suspension seats and handlebars, but more recently in the form of cab and/or axle suspension systems for larger machines only.

Also upper limb movements need attention among forest machines operators and a good analysis method of the problem if offered by the odd ratio. The odds ratio is one of a range of statistics used to assess the risk of a particular outcome (or disease) if a certain factor (or exposure) is present. The odds ratio is a relative measure of risk, telling how much more likely it is that someone who is exposed to the factor under study will develop the outcome as compared to someone who is not exposed. This is estimated by the ratio of the number of times that the event of interest occurs to the number of times that it does not. An odds ratio greater than one implies that the event is more likely in the first group. Among 215 forest machines operators the observed odds ratios for neck and shoulder symptoms were between 2.3 and 4.

Moreover, a study conducted over 909 forest workers showed that 16% had some kind of diagnoses in the locomotor system (Lewark, 2005). The same study shows that musculoskeletal disorders in loggers tend to cause longer sick leaves than accidents.

How to detect the risk to develop these pathologies?

Concerning MSD disorders, many methods have been developed, referring to different work condition: for repetitive static works the NIOSH system has been improved, while in dynamic conditions OWAS, PATH and OSHA may be used.

For WRULD analysis, OCRA, Strain Index and HAL-ACGIH/TLV are the most common systems. Among these, the OCRA method may be successfully used in forestry. The OCRA (OCcupational Repetitive Action) (Colombini, 1998) method is particularly indicated for exposure analysis to tasks concerning various upper limbs risk factors (load, awkward postures, repetitiveness, lack of recovery periods). The method has been applied in different working sectors that involve repetitive movements and/or efforts of the upper limbs. It consists in a index (Occhipinti, 1998) calculated as the ratio between the actually technical actions carried out in the work as repetitive tasks and the number of technical actions recommended (OCRA index). Higher is the OCRA index, more severe is the risk to develop MSDs.

The vibration doses to the body and to the hand-arm system may finally be detected. The European Union Physical Agents (Vibration), Directive 2002/44/EC, specifies both practical limits for daily personal vibration exposure, and (lower) levels above which employers should take steps to reduce exposure. In the Directive the HAV and the WBV are defined. The hand-arm vibration is the mechanical vibration that, when transmitted to the human hand-arm system, entails risks to the health and safety of workers, in particular vascular, bone or joint, neurological or muscular disorders. The whole-body vibration is the mechanical vibration that, when transmitted to the whole body, entails risks to the health and safety of workers, in particular lower-back morbidity and trauma of the spine. In the Directive exposure limit values and action values are established and standardized to an eight hour reference period.

For hand-arm vibration, the daily exposure limit value (ELV) is 5 m/s^2, while the daily exposure action value (EAV) 2,5 m/s^2. For whole-body vibration, the daily exposure limit value (ELV) 1,15 m/s^2 and the daily exposure action value (EAV) is 0,5 m/s^2.

2. MATERIALS AND METHODS

To evaluate the risk of MSD in forestry, this study is based both on OWAS posture work analysis and on hand arm plus whole body vibration exposure regarding two different logger groups in forestry yards of the Valle d'Aosta Region (managed by the Regional Department of Agriculture and Forestry) in the north-west part of Italy at 1500 meters over the sea level, in a very sloped mountain area.

In the first yard, mechanical trees and branches cut other than manual log extraction have been analysed, while in the second skidding and log stacking have been considered. While the cutting phase has always been performed with the use of the chainsaw, the manual extraction has been done with a short-handled timber hoe, while the log stacking has been executed by a couple of loggers manually lifting the logs on a pile after the logs have been moved near by a tractor. After the cut of tree and branches, the logs were manually pushed down to reach the nearest street border. All the logs were measured and, according to the volume, their mass was calculated, using the volume relative mass for each tree type. Then the static and dynamic weights were calculated, referring to each operation phase.

The work team consisted of eight loggers and five of them were considered in this study, aged between 40 and 50 years. Only one of them used the chainsaw, another one was the tractor driver, and the others performed only the manual log movements. In order to comply with the safety guidelines of the last years (European Agency, 2005), in addition to the work posture analysis for each working activity, the vibration risks have been examined.

2.1 Posture Analysis

During the trees and branches cut phase, the operator used a 6 kg chainsaw. For limbing and bucking the hoe (1.8 kg) has also been used, other then the bush knife and the peavey (1.5 kg). For the manual log extraction, the four operators used the hoe to move the logs (without branches and with bark) and let them to glide in natural ground dells to the collecting point. The log length was between 3 and 7 meters and the diameter between 10 and 30 cm.

Three operators were present at the skidding operation and one of them was the tractor driver. The operators moved the logs with the hoe on the street and attached them with chains to the pulley of the tractor. Then the logs were trailed for about 500 meters to the stacking point. For the log stacking, four operators were present to detach the logs from the tractor: two operators stacked one log each time, lifting it from the ground.

2.1.1 The OWAS Method to Measure the Working Posture Safety Risk

The OWAS (Ovako Working-posture Analysis System) system was used to identify and evaluate working postures. This methodology has been widely used in the past (Karhu *et al.*, 1981), codes 252 posture combinations (4 for the back, 3 for the arms, 7 for the legs and 3 for the load) and it is based on observation. Each posture is expressed with a number code (e.g. the code 2162 means bending back, arms under the shoulder, kneeling with 1 or 2 knees touching the floor and a weight to move between 10 and 20 kg).

After recording all postures by the observation of the work cycles, the data analysis follows. A coloured scheme is used, where it is possible to find out the necessity of interaction (figure 2):

1. class 1: the green cell is connected to normal postures with no discomfort and no effect on health, without any special attention except in some cases;
2. class 2: the yellow cell refers to postures which must be considered during the first check of the used working methods;
3. class 3: the orange grey cell means postures which need consideration as soon as possible;
4. class 4: the postures in the red cell need immediate action.

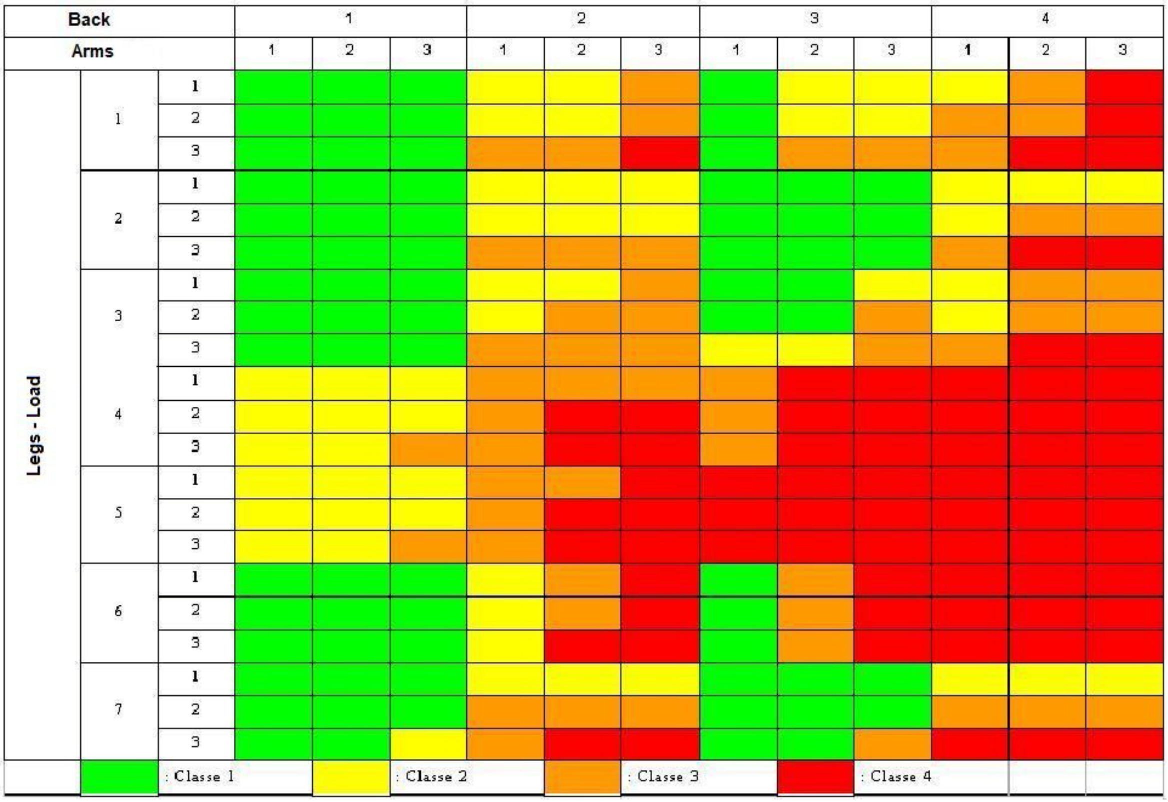

Figure 2. OWAS classes

When all codes have been determined for a specific work, the related index risk I is calculated. It is before necessary to calculate the frequency rate in each OWAS class. The index risk formula is:

$$I = [(a \cdot 1) + (b \cdot 2) + (c \cdot 3) + (d \cdot 4)] \cdot 100$$

where:

a, b, c and d are the frequency observation rates in class 1, 2, 3 and 4 respectively. The index risk ranges between 100 (100% of posture observations in class 1) and 400 (100% of posture observations in class 4): more the risk factor is close to 400, higher a MSD risk does exist.

Concerning data collection and elaboration, for each phase and for each operator, all the postures and the moved weight have been evaluated and 825 risk classes have been calculated.

2.2 Vibration analysis

Because of the risk presence of WBV and HAV for the operators using the chainsaw and the tractor, the daily exposure vibration value for each exposed worker was calculated, considering both the real time when they were at the contact with the vibrating surface and the acceleration values (a_{vi} for the whole body and a_{hweq} for the hand-arm system) for all the used machines. At the end, considering the daily used time (*T*), the daily exposure value *A(8)* was calculated.

2.2.1 HAV

To obtain the correct exposure times in the different work phases, the idling condition (chainsaw switches on in the operator’s hands, without performing any type of work), the racing (corresponding to an engine speed of 133% of the speed at maximum engine power, when the operators starts to cut) and the full load condition (cut phase), were considered, according to the CEN/TR 15350. To have a more detailed picture, both right and left hand vibration measurements were carried out, separating the obtained results.

All the hand-transmitted vibration magnitudes (which are expressed as a frequency weighted root mean square acceleration value – RMS - in units of meters per squared second, as defined in EN ISO 5349-1) have been revealed on the chainsaws using a triad of mono axial accelerometers positioned on aluminum blocks fixed over each handle: then they were connected to a vibration meter (HVM100, Larson Davis) put over the operator’s belt. In this way the logger was free to work without any kind of obstacles. The accelerations was measured using the accelerometers over the three perpendicular directions x, y and z to obtain the vibration value for each operative condition (idling, racing and full load), to permit the calculation of the total acceleration value (a_{hweq}), used to calculate the *A(8)* value, as requested by the 2002/44 EC Directive:

$$A(8) = a_{hweq}\sqrt{\frac{T}{T_o}} \quad \text{m/s}^2$$

(T_0 represents the number of working hours/day, assumed to be equal to 8 hour).

2.2.2 WBV

To measure the whole body vibration, the same vibration meter (HVM100) has been used, connected to three mono axial accelerometers inserted into a rubber structure, fixed to an aluminum disk (inserted between the tractor seat and the operator’s body).

Also in this case the acceleration value along the three axes has been furnished, to calculate the vibration total value a_{vi}, as indicated by the ISO 2631-1: 1997. The daily exposure value *A(8)* was then calculated, starting from the a_{vi} furnished by the instrument and from the sitting time *T* (when the operator was sit on the moving tractor):

$$A(8) = a_{vi}\sqrt{\frac{T}{T_o}} \quad \text{m/s}^2$$

2.3 Machines and Time Characteristic

The tractor type for the WBV analysis (57 kW of power) was used 6 hours/day during skidding, while the two chainsaws (4.6 kW and 4.8 kW of power) were used 3.5-4 hours/day.

3. RESULTS

3.1 Posture Results

During the cut operations the logger was kneeling or standing with the weight on one or two legs, twisting or bending the back and the arms always under shoulder height. For example, the OWAS code analysis of the cut mark realization was 4131, which falls in class 2.

During the manual log extraction the operators normally worked with bended or twisted back, standing with the weight on one leg or the knees bent, the arms below shoulder level and the moved weight higher than 20 kg (a frequent code was 4173, class 4).

In the skidding the two operators that moved the logs with the hoe on the street and attached them with chains to the pulley of the tractor worked with a bended back, the body weight on one leg or one knee bent, the arms below shoulder height, the weight over 10 kg.

For the log stacking, two operators stacked one log each time, lifting it from the ground and working with the straight back and the knees bended at the beginning of the movement, to finish with straight back and with the weight over the 2 legs (code 2143, class 3).

The elaboration of the collected data highlights the presence of the OWAS posture codes especially in class 3 and in class 4 for all the operations. The consequence is the high frequency rate both in class 3 and in class 4 in the two forestry yards, independently from the performed works.

Concerning manual log extraction, the presence of posture codes in class 4 is high for three operators (49% of the total, figure 1), while manual log stacking has the highest values in the third class (86% and 83%, figure 2). For the cut operation the class 2 is predominant (46% and 60%, figure 3 and 4), also if high frequency rates are found in class 4 in both yards. The class 1 is almost absent in all the cases. These numbers underline the severe risk for the operators to develop MSD.

Considering the different parts of the body, twisted and bended back is present in 43% of the observed back postures during the manual log extraction. In this operation, for the legs, knees bent are also revealed in 31% of the total observed leg postures. Load is an important factor to determine posture values in class 3 and 4, both for the manual log extraction and manual log stacking: in fact during these operations the 65% of the moved load is over 20 kg.

Moreover, all the operations in both yards are characterized by high index risks: in both the yards all the index values are around 300. Also if manual log extraction reports the highest absolute value (326), other activities are not too much lower. For the cutting phase the average index risk is 287, for the manual extraction the average increases to 311, while 300 is the average index risk for the manual log stacking.

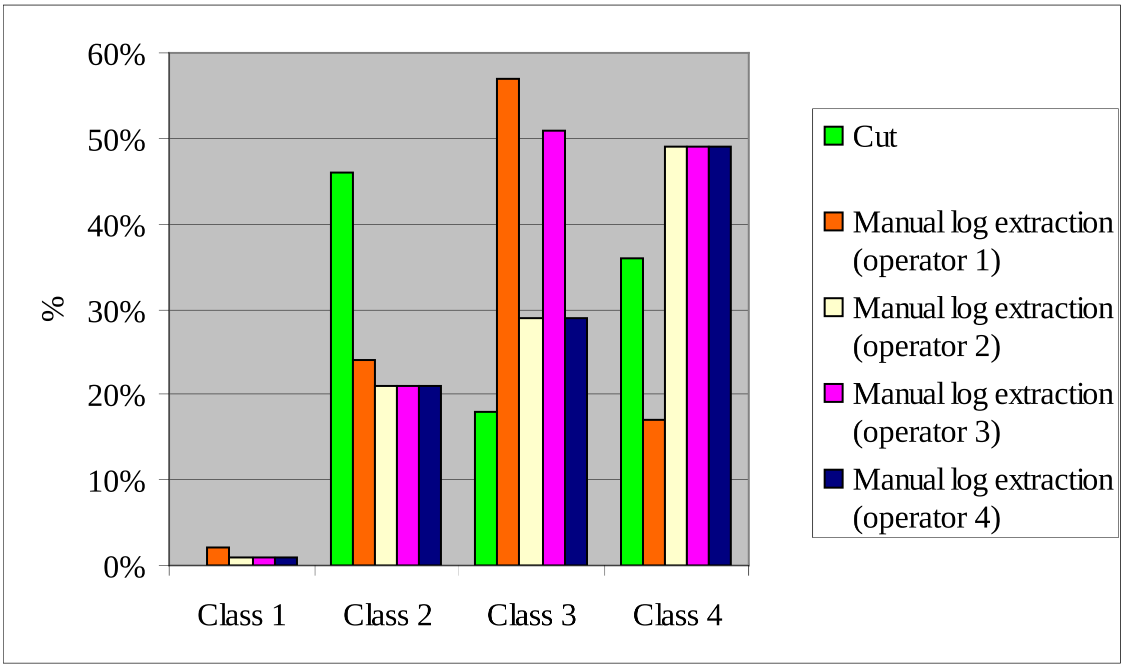

Figure 3. Frequency rates in the OWAS classes (yard 1)

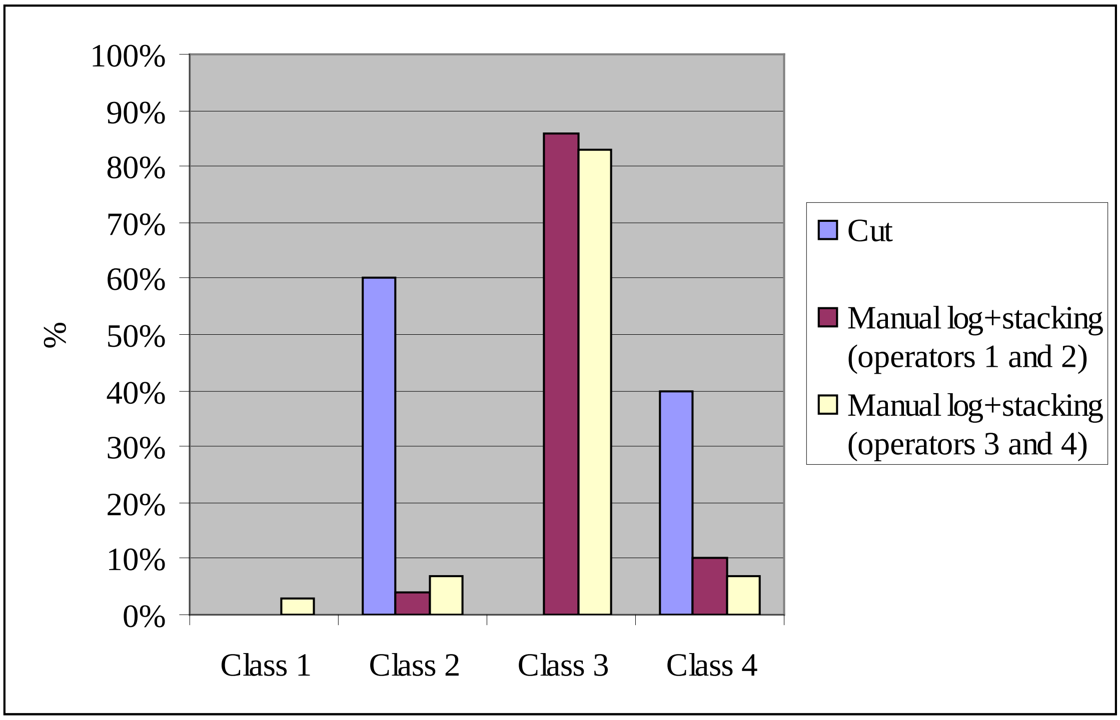

Figure 4. Frequency rates in the OWAS classes (yard 2)

3.2 Vibration Results

The advantage of lower OWAS index risk values in cut operation is lost considering the HAV values transmitted from the chainsaws to the operator's hand-arm system.

Also the operator using the tractor during the log stacking is heavily affected by WBV while he sits on the tractor: in fact, the obtained value is over the daily exposure action value, as stated by the 2002/44/EC Directive.

For the WBV, the calculated *A(8)* amounts to 0.9 m/s^2 for the operator who drives the tractor: also when he does not perform manual works, the fact that he sits on the tractor and he drives on an uneven ground, it does not ensure him that he will not risk low back pain.

For the HAV, the situation is worst (table 1), because 3 of the 4 calculated values (red coloured in the table and referred to two different chainsaws) are over the daily exposure limit value (this means that immediate actions must be considered to reduce these numbers). The cut operation expose loggers not only to low back pain risk, but also to upper limbs risk.

Table 1. Daily *A(8)* values during the cut operation

Chainsaw	Daily *A(8)* values (m/s^2)
Right hand. Chainsaw 1	6.1
Left hand. Chainsaw 1	3.7
Right hand. Chainsaw 2	6.5
Left hand. Chainsaw 2	5.3

4. CONCLUSIONS

It is not easy to state some proposals in order to improve forestry works as cut and manual log extraction and stacking, with the aim to reduce both the OWAS index risk and the HAV – WBV daily exposure values. The high results obtained in this work are due to the difficult environmental situation of the examined forestry yards (high slope, irregular ground with the presence of musk and branches) and to the machinery type (especially chainsaw). In the high mechanized forestry yards, where processor, forwarder and harvester are present, a major productivity may be associated with ergonomic side effects. For the lumberjacks, heavy manual tasks have been replaced by long period of lever operations placing a low and static load on the shoulder-neck region, plus a long period of whole body vibration transmitted by the seat of the vehicle (an interview of 118 forestry machine workers showed that most skidders report low back problems caused by vibrations of their machine seats) (Walker *et al.*, 2005).

It seems that mechanization is not a panacea to solve MSD risks for the loggers: however, some indications can be useful. One of the most improved way to reduce the risk is to increase the number and the duration of the pause; in this way the OWAS and the OCRA frequencies become lower and the *A(8)* is positively affected too, because the exposure time to the vibration source diminishes.

Also a good tractor and chainsaw maintenance may reduce induced HAV and WBV vibrations. In mechanical advanced forestry yards, the high mental demands on the operator may appear to be more important than the mechanical work demands: in this case the most effective strategy to prevent musculoskeletal disorders is probably to reduce the duration of lever operation and to add other tasks in order to achieve an enriched job exposure.

Training is also important: to train and to inform operators about the correct positions and the manual movement techniques may reduce many incorrect postures.

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