Work-related musculoskeletal disorder and vibration risk in forestry

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Abstract - Kurzfassung

In forestry yards we find hard environmental conditions and dangerous tools and machinery such as chainsaws. In this context forestry workers are exposed to many safety risk factors: injuries, noise, hand-arm and whole body vibrations, dust, back pains, manual work load. The high manual work load is tiring and can cause work-related musculoskeletal disorder (MSD) amongst the loggers. This pathology increases with the component 'vibration' induced by chainsaws, tractors, skidders and other machinery. In fact, both the Whole Body Vibration (WBV) and the Hand Arm Vibration (HAV) have been detected as important risk factors, which must be strictly controlled. In this study we consider two different logger groups working in public forestry yards and we analyze their MSD risk exposure, using the Ovako Working-posture Analysis System (OWAS) technique and the 2002/44/EC vibration Directive. In the first yard, mechanical tree felling using chainsaws and manual deforestation are the tasks performed; in the second yard, the operations are mechanical tree felling and log stacking using a tractor also. The work of five loggers was analyzed, evaluating all risk types. The result was that both the OWAS index and the vibration indicators were quite high. This demonstrated the critical situation for forestry workers.

Keywords: OWAS, forestry, vibration

Bewertung der Verletzungsgefahr für die Muskulatur und das Skelett bei Forstarbeiten

Im Forst werden bei schlechten Umweltverhältnissen, schwere und gefährliche Werkzeuge und Maschinen wie z.B. Kettensägen eingesetzt. Unter solchen Umständen sind die Arbeiter auf unterschiedliche Weise gefährdet: Verletzungen, Lärm, Hand-Arm- und Ganzkörper-Schwingungen, Staub, Rückenschmerzen, Belastung durch Handarbeiten u.s.w. Ein sehr ermüdender Teil sind schwere Handarbeiten, die eine der Ursachen von Schädigungen des Muskel/Skelett (MSS)-Bereichs ist. Diese Krankheitserscheinungen nehmen mit den von Kettensägen, Schleppern, Miniladern und anderen Maschinenausrüstungen verursachten Schwingungen zu. Tatsächlich wurden sowohl „Whole Body Vibration“ (WBV) als auch „Hand Arm Vibration“ (HAV) als sehr bedeutende Gefährdungsfaktoren ermittelt, die einer strengen Kontrolle unterliegen müssen. In unserer Arbeit untersuchen wir zwei verschiedene Gruppen von Forstarbeiten. Dabei wird die Gefährdung des MSS unter Anwendung des „Ovako Working-posture Analysis Systems“ (OWAS) und der Richtlinie 2002/44/EC zur Erfassung der Schwingungsbelastung ermittelt. Die unterschiedliche Arbeitsorganisation hat uns im ersten Forstbetrieb gezwungen, nur das Baumfällen mit Kettensägen und Handarbeiten zu analysieren; dagegen konnten im zweiten Betrieb das mechanische Baumfällen und die Baumstapelung auch mit Einsatz von Schleppern und Ladern betrachtet werden. Fünf typische Forstarbeiten wurden betrachtet und hinsichtlich aller Gefährdungspotenziale bewertet. Das Ergebnis bestätigt, dass der OWAS-Index und die Schwingungsbelastung recht hoch waren. Somit herrschen bei den Forstarbeiten sehr kritische Arbeitsbedingungen.

Schlüsselwörter: OWAS, Waldbau, Schwingung

1 Introduction

The Risk Observatory of the European Agency for Health and Safety has identified the major emerging risks related to occupational safety and health of workers and employers (European Agency for Safety and Health at Work 2005).

In this context European experts of 15 countries were surveyed to identify the emerging occupational safety and health physical risks. 137 experts were approached, 66 questionnaires were returned. A five-point Likert scale was used to interpret the results. The scale ranged from 'disagree' to 'agree': the scale value '1' meant 'strongly disagree that the issue is an emerging risk', while the scale value '5' was a 'strongly agree that the issue is an emerging risk'. In Fig. 1 the top emerging risks are presented, as well as their associated Likert value. Vibration, awkward postures, muscular work and musculoskeletal disorder (MSD) are present, demonstrating their relevance.

During the last decade, several studies have been carried out regarding these aspects (Ashby et al. 2001, Bovenzi & Hulshof 1998, Colombini & Occhipinti

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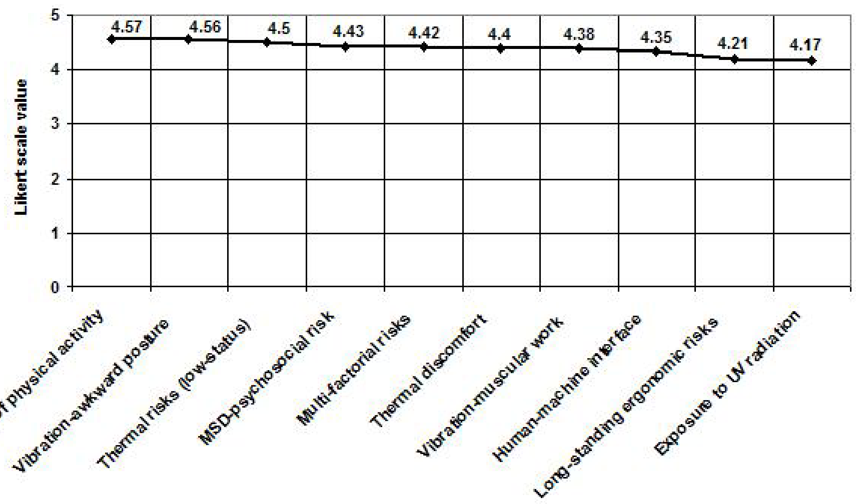

Fig. 1: The top emerging physical risks identified by the Risk Observatory of the European Agency for Health and Safety (years: 2002-2006)

2004, Gemne 1997) and, at occupational disease level, the consequences are demonstrable.

The term MSD involves all pains referring to nerves, tendons, muscles and the supporting structures of the body. The MSD also includes low back pain, shoulder and distal upper extremity disorders (Waters 2004), as well as muscular skeletal diseases of upper limbs. Workers like loggers who work in forestry yards can develop these injuries, due to lifting heavy objects, working in awkward positions for a long period of time, being obliged to twist or to bend themselves in sloped areas with a high risk of falling or slipping, using heavy and dangerous machineries like chainsaws and, finally, because they sit on tractors and drive over uneven ground.

Frequent manual handling of machine equipment (as chainsaws), stooping or kneeling postures (i.e. during manual extraction in sloped areas) and tractor driving have been associated with low back pain (Ashby et al. 2001). Frequent manual material handling tasks and work with hands above shoulder height have been associated with neck and shoulder pain (Holstrom et al. 1993).

Despite the help of machinery, these occupational diseases tend to be serious in our society (NRC 1999) and account for a major component of the costs of work-related injuries and illness. For example, the cost of the low back pain in the USA in the nineties was around 49 billion of dollars per year (Leigh et al. 1997). The 30-40 % of the German forestry workers suffer of back pains caused by manual weight lifting or by awkward positions and in Italy the lumbago is one of the principal professional illnesses in the timber work sector (Cavalli & Menegus 1997).

The vibration transmitted to the body by mechanical tools has to be distinguished between hand-arm transmitted vibration (HAV) problems and whole-body vibration (WBV) pathologies (Griffin 1990).

Muscular skeletal disorders of the upper limbs are most prevalent amongst occupational diseases in many industrialized countries, like Italy (Colombini & Occhipinti 2004): prolonged exposure to hand-transmitted vibration is associated with an increased occurrence of symptoms and signs of disorders in the vascular, neurological and osteoarticular systems of the upper limbs. The complex of disorders is called hand-arm vibration syndrome. An increased risk for upper-limb muscle and tendon disorders as well as for nerve-trunk entrapment syndromes has also been reported in workers who use hand-held vibrating tools (Gemne 1997). The percentage of workers exposed to hand-arm vibration varies between European countries: 5 to 11 % are exposed to HAV from hand tools (Donati et al. 2007).

The WBV exposure is also a widespread occupational risk factor. In the USA, in Canada and in some European countries, it has been estimated that around 7 % of the employees are exposed to harmful WBV (Bovenzi & Hulshof 1998).

The Directive 2002/44 of the European Parliament and Council of 25 June 2002, regarding the professional exposure to the mechanical vibration, has activated a specific policy of preventive and safeguard measures concerning this risk factor. Article 3 of this Directive introduces the daily vibration exposure limit value and the daily vibration exposure action value transmitted to the whole body and to the hand-arm operator system by vibrating tools, referred to a 8 hours working period.

For hand-arm vibration, the Directive sets:

– the daily exposure limit value standardized to an eight-hour reference period is 5 m/s^2;

- the daily exposure action value standardized to an eight-hour reference period is 2,5 m/s^2.
- For whole-body vibration:
- the daily exposure limit value standardized to an eight-hour reference period is 1,15 m/s^2;
- the daily exposure action value standardized to an eight-hour reference period is 0,5 m/s^2.

The prevalence of several risk factors during forestry work let us perform a study considering two different logger groups working in public forestry yards, to analyze the contribution of their MSD risk exposure using the OWAS (Ovako Working-posture Analysis System) technique and the vibration Directive (Directive 2002/44/EC 2002). Aim of the work was to examine the posture and vibration data together in a critical environmental situation where forest works are performed.

2 Methods used to evaluate the working posture safety risk

2.1 Visual methods

Different visual methods to measure the working posture safety risk exist, for example NIOSH (National Institute of Occupation Society and Health), OCRA (OCcupational Repetitive Action) and OWAS (Ovako Working-posture Analysis System).

2.1.1 NIOSH and OCRA

The NIOSH method is based on the guideline to give an ideal weight and to adjust it by factors: these factors can be used to improve job designs. Although there are a number of ways of deriving these factors, they are primarily based on biomechanical and psycho-physiological factors, with a cardio-vascular approach for highly repetitive lifting. This method is well known in many countries, but it is useful for repetitive static work only.

The OCRA method (Colombini 1998) is particularly indicated for exposure analysis of tasks concerning 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. The evaluation results in the OCRA 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. The higher the OCRA index is, the more severe is the risk to develop MSDs.

2.1.2 OWAS

The Ovako Working-posture Analysis System (OWAS) has been widely used to identify and evaluate harmful working postures (Karhu et al. 1981). OWAS codes 252 posture combinations (4 for the back, 3 for the arms, 7 for the legs and 3 for the load, Fig. 2) and it is based on observation (Lundqvist & Gustafson 1987). Each posture is expressed with a number code e.g. the code 2162 means bended back, arms under the shoulder height, 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.

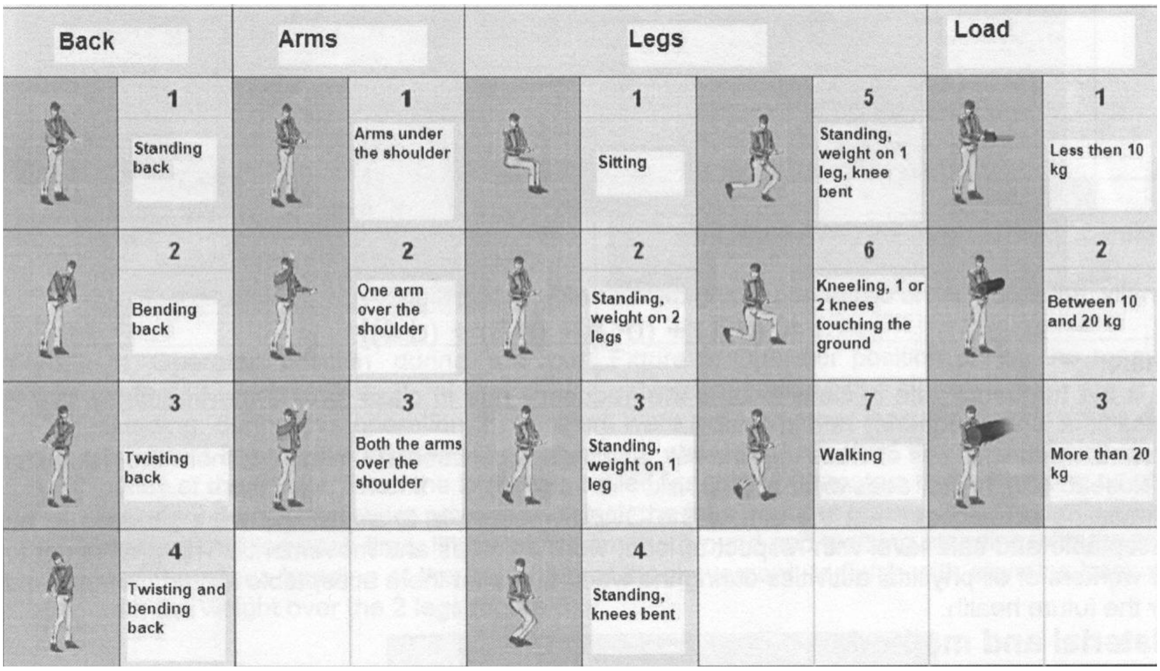

Fig. 2: The 252 OWAS combinations

A coloured scheme is used, where it is possible to find out the necessity of interaction (Fig. 3):

1. class 1: the black pick 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 light grey cell refers to postures which must be considered during the first check of the used working methods
3. class 3: the dark grey cell means postures, which need consideration as soon as possible
4. class 4: the postures in the black cell need immediate action.

As shown in Fig. 3, it is possible to find the fourth class with a quite low code, as 2313 which indeed refers to a critical situation: sitting, more than 20 kg to move, bending back, both arms over the shoulder. It takes lot of time to define all possible codes, especially if the work is dynamic: for this reason a camera can be useful to record the work phases. When all codes have been determined for a specific work, the related risk index *I* (Lundqvist & Gustafson 1987) is calculated. Before it is necessary to calculate the frequency rate of the codes in each OWAS class. The risk index formula is:

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

where *a*, *b*, *c* and *d* are the frequency rates in class 1, 2, 3 and 4, respectively. For example, if we observe 32 postures in class 1, 0 in class 2, 0 in class 3 and 8 in class 4, *a* is equal to 0.8, *b* and *c* are 0 and *d* value is 0.2. The risk index is 160.

The risk index ranges between 100 (100 % of posture observations in class 1) and 400 (100 % of posture observations in class 4); the higher the risk factor is the higher is the risk to suffer from MSD.

One of the limits of this methodology is that it does not take into account the position of some other parts of the body, connected to possible MSD risks, as the neck and the head. Another limit is that the number of body postures in different classes is not necessarily related to the actual duration within the work tasks. A further limit is the regarded load: sometimes a dangerous tool less than 10 kg to be moved, like a chainsaw, may cause problems as well.

2.2 Hand-arm transmitted vibration (HAV) and whole-body vibration(WBV) analysis

The assessment of the level of exposure to hand-arm vibration is based on the calculation of the daily exposure value referring to an eight-hour reference period (*A(8)*), expressed as the square root of the sum of the squares (RMS total value) of the frequency-weighted acceleration values, determined on the orthogonal axes a_{hwx}, a_{hwy}, a_{hwz} as defined by the standard ISO 5349-1 (2001).

In the same way, the assessment of the level of exposure to whole body vibration is based on the calculation of the daily exposure *A(8)* expressed as equivalent continuous acceleration over an eight-hour period, calculated as RMS value on three orthogonal axes (a_{wx}, a_{wy}, and a_{wz} for a seated or standing worker) in accordance to the standard ISO 2631-1 (1997).

The assessment of the level of exposure may be carried out by estimation based on information provided

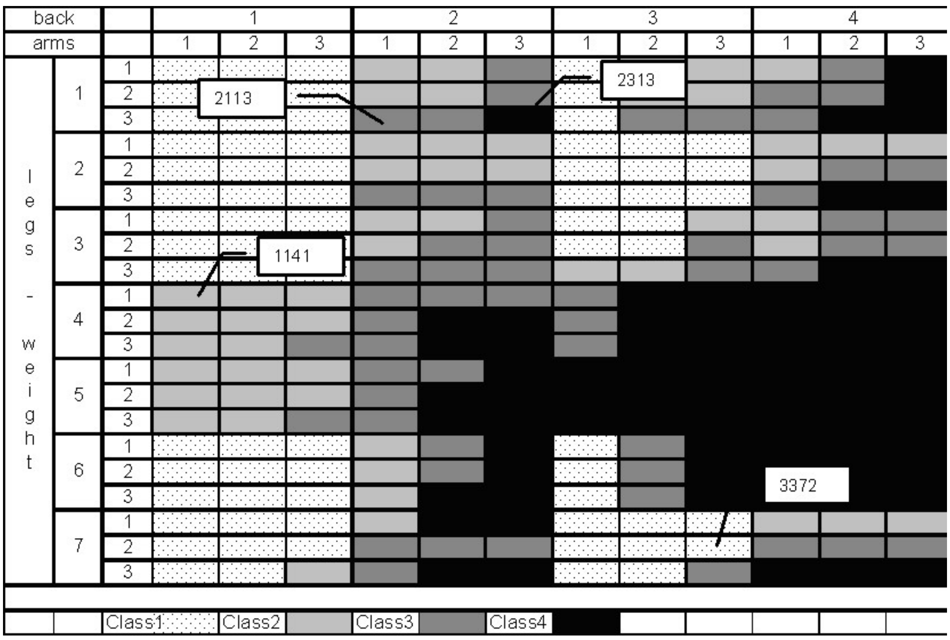

Fig. 3: The four classes OWAS scheme

by the manufacturers concerning the level of emission from the work equipment used, and based on the observation of specific work practices or on measurement.

3 The MSD analysis in a forestry yard: material and methodology

To evaluate the risk of MSD for forestry workers, a study has been carried out based on OWAS working posture analysis and hand arm and whole body vibration exposure, regarding two different logger groups in the forestry yards of the Valle d'Aosta Region, in the north-western part of Italy.

The analyzed yards are managed by the Regional Department of Agriculture and Forestry of Valle d'Aosta and are located 1,500 meters above sea level, in a very sloped mountainous area. The examined forest is composed by spruce (*Picea* sp.) and Scotch pine (*Pinus sylvestris*) with the presence of larch (*Larix* sp.). The estimated age of the wood is about 50-60 years and in the past corn and rye were cultivated. Today only the little dry-stone walls are present, originally preventing erosion.

In the first yard mechanical trees and branches cut other than manual log extraction have been analyzed, in the second yard skidding and log stacking have been considered. In both yards, operators' postures and related time in each posture were examined and data were collected using a special form. A camera was useful to validate the field collected data.

The cutting phase has always been performed by using a chainsaw, the manual extraction has been done with a short-handled timber hoe and 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.

It must be considered that the manual work load was also high during the mechanized forest operations, because of the soil structure: slopes among 38° and 40°, slippery and uneven ground due to the presence of musk and broken branches (Fig. 4). The use of tools like pulleys and sleds is impossible in this kind of terrain. After the cutting of trees 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 for Safety and Health at Work 2005), in addition to the work posture analysis for each working activity (according with the OWAS scheme), the vibration risks have been examined (hand-arm for the chainsaw operator and whole body for the tractor driver).

Fig. 4: The forestry environmental conditions

3.1 OWAS application

During the tree and branch cutting phase the operator used a 6 kg chainsaw. For limbing and bucking, the hoe (1.8 kg) was also used, other then the bush knife and the peavey (1.5 kg). During these 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.

For the manual log extraction, the four operators used the hoe to move the logs (without branches and with bark) and to let them 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. During this phase 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).

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. The two operators worked with a bended back, the body weight on one leg or knee bent, the arms below shoulder height, the weight over 10 kg. In this operation different types of risks were present: for the tractor driver noise and vibration and for the operators MSD, awkward postures, thermal discomfort and noise.

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 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).

Concerning data collection and elaboration, for each phase and for each operator, all the postures and the moved weight have been evaluated by calculation of 825 risk classes. For each posture the surveyed time was also considered (Table 1).

The WINOWAS software (Tampere University of Technology, Occupational Safety Engineering 1996) was used to test the procedure. The program, other than to collect data in the field, is able to directly calculate the risk classes and the frequency rate starting from the input operators positions.

3.2 Vibration analysis

To evaluate the daily operator's vibration dose, it was necessary to know the machine characteristics, as well as their daily utilization time. The tractor type was a CARRARO (57 kW), used 6 hours/day during skidding, while the chainsaws were HUSQUARNA 372 XP (4.6 kW) and STIHL 064 (4.8 kW); both of them were used 3.5-4.0 hours/day.

3.2.1 Hand-arm transmitted vibration (HAV)

The chainsaws utilization times have been calculated on the basis of their real utilization. To obtain the correct exposure times in the different work phases, the idling condition (chainsaw simply 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. 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 (ISO 5349-1 2001) have been revealed on the chainsaws using a triad of mono axial accelerometers positioned on aluminum blocks fixed over each handle (Fig. 5): 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.

Fig. 5: Accelerometers positioned over the chainsaw handles

The accelerations have been measured using the accelerometers over the three perpendicular directions x, y and z to obtain the vibration total value a_{hw}:

$$a_{hw} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \text{ m/s}^2 \quad (2)$$

Table 1: Scheme for the data collection and elaboration

Sample	Time (s)	Log weight (kg)	Moved weight (kg)	Back code	Arms code	Leg code	Weight code	OWAS code	Risk class
1	6	51.3	25.7	2	1	4	3	2143	3
2	9	40.5	20.3	2	1	4	3	2143	3
3	6	13.5	6.8	2	1	4	1	2141	3
4	6	42.8	21.4	2	1	4	3	2143	3
...	...	...	...	...	...	...	...	...	...
23	4	25.7	12.8	2	1	4	2	2142	3
24	9	155.9	77.9	4	1	4	3	4143	4
25	8	83.1	41.6	2	1	4	3	2143	3
26	7	83.1	41.6	2	1	4	3	2143	3
27	5	40.5	20.3	2	1	4	3	2143	3
28	8	103.7	51.9	2	1	4	3	2143	3
29	4	40.5	20.3	2	1	2	3	2123	3
...	...	...	...	...	...	...	...	...	...

This has been done for each operative condition (idling, racing and full load), to permit the calculation:

$$a_{hweq} = \sqrt{\frac{1}{T}\sum_{i=1}^{n} a_{hwi}^2 T_i} \qquad \text{m/s}^2 \qquad (3)$$

where

a_{hwi} - represents the measured acceleration at the '*i*' operative condition (idling, racing or full load)

T_i - is the utilization time at the '*i*' operative condition (minutes)

T - is the total contact time with the vibrating tool (minutes)

The *A(8)* value was then directly calculated:

$$A(8) = a_{hweq}\sqrt{\frac{T}{T_o}} \qquad \text{m/s}^2 \qquad (4)$$

(T_0 represents the number of working hours/day. If there are not special considerations, this value is assumed to be equal to 8 hour, 480 minutes).

3.2.2 *Whole-body vibration (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 aluminium disk inserted between the tractor seat and the operator's body, along the three perpendicular axes for the whole body measurements. Also in this case the acceleration value along the three axes has been furnished, to calculate the vibration total value:

$$a_{vi} = \sqrt{1.4a_{wx}^2 + 1.4a_{wy}^2 + a_{wz}^2} \qquad \text{m/s}^2 \qquad (5)$$

This is the requested formula as indicated by clause 6.5 of ISO 2631-1 (1997) to evaluate the accelerations along the three axes directions. The multiplicative factor 1.4 is requested by ISO 2631-1 (1997) to consider the highest human body sensibility to the x and y axes. In this case we had only one operator using one tractor: for this reason it was not necessary to use the complete formula (similar to (3)), but we simply calculated the daily exposure value *A(8)*, starting from the a_{vi} furnished by the instrument and from the time T when the operator was sit on the moving tractor:

$$A(8) = a_{vi}\sqrt{\frac{T}{T_o}} \qquad \text{m/s}^2 \qquad (6)$$

4 Results

4.1 OWAS

The elaboration of the collected data highlights the presence of the OWAS posture codes especially in class 3 and in class 4 for all operations. The consequence is a 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 two operators (49 % of the total, Table 2), while manual log stacking has the highest values in the third class (86 % and 83 %, Table 3). For the cut operation the class 2 is predominant (46 % and 60 %, Tables 2 and 3), also if high frequency rates are found in class 4 in both yards. The class 1 is almost absent in all the cases. These results underline the severe risk for the operators to develop MSD.

Table 3: Frequency rates in the 4 OWAS classes for the operations 1-4 in the yard number 2

Yard number 2	Cutting	Manual log stacking op. 1 + 2	Manual log stacking op. 3 + 4
Class 1	0 %	0 %	3 %
Class 2	60 %	4 %	7 %
Class 3	0 %	86 %	83 %
Class 4	40 %	10 %	7 %

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

Table 2: Frequency rates in the 4 OWAS classes for the operations in the yard number 1

Yard number 1	Cutting	Manual log extraction (operator 1)	Manual log extraction (operator 2)	Manual log extraction (operator 3)	Manual log extraction (operator 4)
Class 1	0 %	2 %	1 %	1 %	1 %
Class 2	46 %	24 %	21 %	21 %	21 %
Class 3	18 %	57 %	29 %	51 %	29 %
Class 4	36 %	17 %	49 %	27 %	49 %

log stacking: in fact during these operations 65 % of the moved load is heavier than 20 kg. Moreover, all operations in both yards are characterized by high risk indexes (Fig. 6).

From its definition, the risk index is a calculated number between 100 and 400: in these yards all the index values are around 300 (Fig. 6). Although manual log extraction reports the highest values (326 for both operators 2 and 4), other activities are not much lower. For the cutting phase the average risk index is 287, for the manual extraction it increases to 311, while 300 is the average risk index for the manual log stacking. The sloped area and the irregular and slippery ground oblige the operators to get tiring positions during their work: also the mechanized operation (cutting) is influenced by these factors.

4.2 Vibration

Concerning cut operation, the advantage of lower OWAS risk index values is lost because the vibration values transmitted from the chainsaws to the operator's hand-arm system are high. Although the operator is using the tractor during the log stacking he is heavily affected by WBV while he sits on it. In fact, for both HAV and WBV, the obtained values exceed the daily exposure action value, as stated by the 2002/44/EC Directive.

For the WBV, the calculated *A(8)* amounts to 0.901 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 does not guarantee that he will be free of low-back pain.

For the HAV, the situation is worst (Table 4), because 3 of the 4 calculated values (referred to the same operator working with two different chainsaws) are above the daily exposure limit value. That means that immediate actions have to be considered to reduce these numbers. The cutting operation exposes loggers not only to low-back pain risk, but also to upper limbs risk.

Table 4: Daily *A(8)* values during the cutting operation

Measurement points	Daily *A(8)* values (m/s^2)
Husqvarna 372 XP, rear handle	6.1
Husqvarna 372 XP, front handle	3.7
Stihl 064, rear handle	6.5
Stihl 064, front handle	5.3

5 Discussion

In this study, forestry work presents high vibration and OWAS postures values. Almost all the HAV data are above the daily values permitted by the European directive. Both the WBV values and the OWAS risk indexes inform that immediate attention is required.

It is not easy to state some proposals in order to improve forestry work like felling, manual log extraction and stacking, with the aim to reduce both the OWAS risk index 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). 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 frequency becomes lower and the *A(8)* is positively affected too, because the exposure time to the vibration source diminishes.

Training is also important: to train and to inform operators about the correct positions and the manual

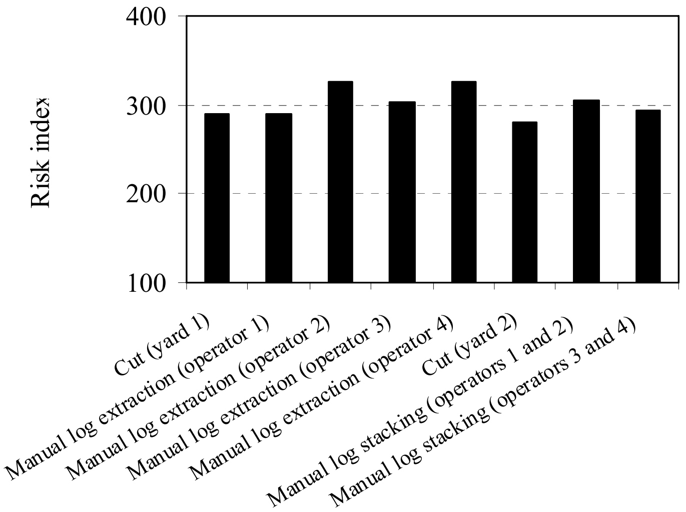

Fig. 6: Risk index values

movement techniques may reduce many incorrect postures.

If it is not possible to reduce the weight of the load, it may be convenient to use little pulleys or sleds for skidding, if possible in the surrounding area. Also a good tractor and chainsaw maintenance may reduce induced HAV and WBV vibrations.

More research is necessary to fully determine how the interactions between the effects of biomechanical load and vibration and other work factors may influence the risk to loggers who are exposed to a wide range of environmental and working conditions. For example, the vibration exposure risk is strictly connected to the thermal discomfort. If machinery builders, occupational health specialists, forest engineers, loggers and the staff responsible for the yards will work together following common research goals, there can be significant gains in reducing the number of workers that may be affected not only by MSD, but also by other physical problems.

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