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Hand-held Olive Beaters: Analysis of the Upper Limb Disorders and Hand-arm Vibration Risks

Angela Calvo[a], Elio Romano[b], Giampaolo Schillaci[*c], Christian Preti[d], Roberto Deboli[d]

[a] DISAFA (Department of Agricultural, Forest and Food Sciences and Technologies), Largo P.Braccini 2, 10095 Grugliasco, Turin, Italy
[b] CREA-ING. Unità di Ricerca per l'Ingegneria Agraria, Via Milano 43, 24047 Treviglio, Bergamo, Italy]
[c] Di3A (Dipartimento di Agricoltura, Alimentazione e Ambiente - Sezione Meccanica e Meccanizzazione) - Università degli Studi di Catania, Via Santa Sofia 100, 95123 Catania.
[d] IMAMOTER Institute for Agricultural and Earth-moving Machines of C.N.R (Italian National Research Council), Strada delle Cacce 73, 10135 Turin, Italy
giampaolo.schillaci@unict.it

Many agricultural workers are exposed both to upper limb muscle-skeletal disorder (ULMSD) and hand-arm vibration (HAV) risks. These risks have been investigated since many years, especially after the law provided to prevent the hand-arm vibration and the ULMSD risks in the workplace (the European Directive 2002/44 and the ISO 11228-3. 2007). These risks are unfortunately evaluated separately. This work analysed the above mentioned risks using both the OCRA index and the daily operators' exposure to HAV (A(8)) in the olive harvesting operation using hand-held beaters. These machines (quite light, but with both a long shaft and high sticks velocity) record high vibration values and oblige the workers to accomplish repetitive movements with the upper limbs, often with the arms above the shoulders. In this work the OCRA index and the A(8) were calculated for five operators using an electric olive beater: in all the cases the A(8) and the OCRA index exceeded the daily exposure values (the average A(8) was between 13.3 and 21.5 ms^{-2} and the OCRA indices ranged from 20 to 32). ULMSD and the physical consequences of the vibration are evident only after some years, but the related pathologies are not often completely recoverable. Hand-held olive beaters are quite new machines, but it is important to correctly evaluate both the ULMSD and the vibration risks, to avoid the increment of the related pathologies.

1. Introduction

Many tasks expose farmers and agricultural workers to a variety of physical hazards. They contribute to the increment of the declared professional illness: in Italy an increase of 92% was observed in the period 2010-2015 (INAIL, 2017, Figure 1).

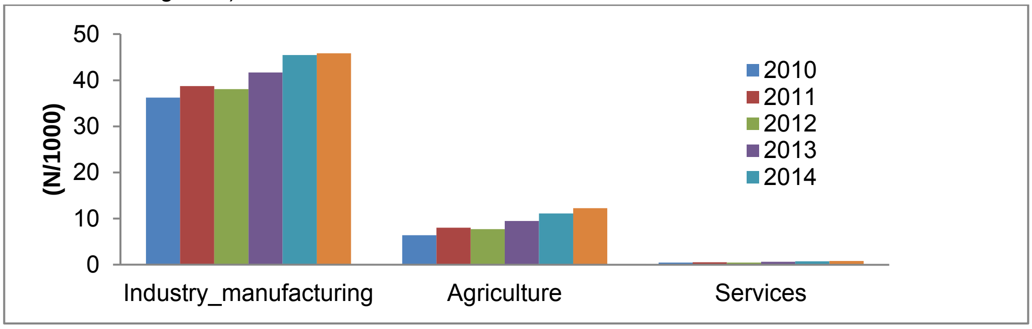

Figure 1: Number (N) of professional illness declared in Italy in the period 2010-2015 (Source: INAIL data, elaborated by the Authors).

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In the same years, the WRMSDs (Work Related Muscle-Skeletal Disorders) increased from 19,912 (2010) to 37,339 (2015) and in 2015 their incidence among the professional illness was more than 60% (Table 1).

Table 1: Professional illness and WRMSDs observed in Italy in the period 2010-2015 (source: INAIL data elaborated by the Authors)

	2010	2011	2012	2013	2014	2015
Professional illness	43,083	47,311	46,285	51,827	57,370	58,917
WRMSDs	19,912	25,500	26,508	30,547	35,465	37,339
%	46%	54%	57%	59%	62%	63%

Despite the technological evolution, also agricultural workers are still exposed to a variety of WRMSDs: low back pains, upper limb disorders, osteoarthritis, WBV (Whole Body Vibration) and HAV (Hand Arm Vibration) syndromes (Lunner and Jacob, 2016; Davis and Kotowski, 2007; Scarlett et al., 2007).
Unfortunately, musculoskeletal problems develop slowly over years of repeated stresses and epidemiological studies hardly classify them (Kim, 2016). The prevention and an accurate farmers' information are therefore necessary to avoid physical problem that may be not recovered. Moreover, WRMSDs are common among the farmer, that perceive them as a consequence of their work, often continuing to work while injured or sick because self-employed (Naeini et al., 2014). The highest incidence among the work-related muscle-skeletal pathologies in Italy in 2015 was given by the upper limb biomechanical overload (65%, against the 35% of lumber disks herniation). In agricultural sector, upper limb muscle-skeletal disorder (ULMSD) risks were observed among many farmworkers: in dairy farms (Stal, 2000), during crop harvesting (Davis and Kotowski, 2007; Cecchini et al., 2010; Proto and Zimbalatti, 2015), in the meat and vegetable processing (Grieco, 1998, Boubaker et al., 2014).
Hand-arm vibration were analyzed in different agricultural tasks (Dewangan et al., 2009) and the olive harvesting using the hand-held harvester was among the most investigated in the Mediterranean region (Aiello et al., 2010, Çakmak et al., 2011; Pascuzzi et al., 2009, Manetto and Cerruto, 2013). In this area, in fact, there are many hilly olive groves, where it is impossible to harvest the fruits with the self-propelled harvesting machines.
There are different types of hand-held harvesters, but the electric beaters are preferred, because lighter and less noisy.
The olives detachment is not an easy task, because this small fruit is strongly attached to long stalks hanging downward, isolating the fruit from the vibration of the branches. It is therefore necessary having an high tangential velocity at the stick tips to detach the drupes. On the other hand, the mass of the harvester must be low, because the operator inserts the beater sticks into the foliage about 30-40 times/minute for more than 4 hours/day (Deboli et al., 2014). The combination of both the tool lightness (around 2 kg) and the high acceleration of the sticks produces high vibration values, that range between 15-25 ms-2 (Pascuzzi et al., 2009; Aiello et al., 2010; Çakmak et al., 2011). The arms of the operator are therefore over the shoulders and he must exert a continuous force to push the beater in the foliage (Figure 2, left). For these reasons in this work it was investigated the operator's double exposure to hand-arm vibration and to the upper limbs risk due to the beater handling during the olive harvesting. The hand-arm vibration was evaluated using the European Directive 2002/44, while the OCRA method was used to determine the upper limbs risk.

Figure 2: Operator's movements during the beater use (left) and the beater used in this work (right).

2. Materials and methods

Field tests were performed in 2016, November in an hillside olive grove located in the Liguria Region (North-west of Italy) at San Giovanni (municipality of Stella, SV, 44°23' 48" N and 8°29' 36" E). The Leccino variety (*Olea Europea*) is present (the height of the trees is around 250 cm) in this area. The electric beater used in the field tests (Figure 2, right) has an head equipped with six oscillating sticks (carbon fiber, with a stick mass of 19 g). Other beater characteristics are: 1086 beats per minute, 2.2 kg beater mass, 3 m pole length, 12-24V supply voltage. The olive harvesting was performed by five skilled operators (right handed): for each of them all the movements and the body postures were analysed during the beater use for the calculation of the OCRA index. Acceleration measurements were carried out by two tri-axial accelerometers (ICP - Integrate Current Preamplifier -, PCB SEN020 model, 1 mV/g sensitivity, 10 g mass) positioned at both the front and the rear hand position of the beater pole. Acquisitions were carried out in the idling state and during the field work. Operators' age was between 35 and 66 years old, with a mass between 71 and 98 kg and an height in the range 175-187 cm. The EN ISO 20643/A1 standard was used for the vibration total values (a_{hv}) measurements (all the measures were repeated three times) and the CEN/TR 15350:2013 was the guideline to calculate the equivalent vibration total value $a_{hv,eq}$ (obtained by the highest a_{hv}, in this case acquired in the front hand position). The $a_{hv,eq}$ was therefore used to calculate the daily exposure *A(8)* for each operator (Directive 2002/44/EU) Eq(1).

$$A(8) = a_{hv,eq}\sqrt{\frac{T}{T_0}} \tag{1}$$

where:
$a_{hv,eq}$: equivalent vibration total value
T: working time with the beater switched on
T_0: 8 hours
The observed daily use of the beater switched on was 5 hours. The harvesting work was recorded using a PJ530 Handycam camera (Sony). The videos were used to analyse the posture and the movements of the workers, as well as to obtain the parameters for the calculation of the OCRA index (as required by the ISO 11228-3:2007). Each operator was also interviewed both to have their feeling concerning the stress and the fatigue level and to evaluate the force exerted when using the beater. The work times and the duration of each work-phase were also recorded, accordingly to the OCRA method (Colombini and Occhipinti, 2006). The Ocra index (*Oi)* was therefore calculated, Eq (2), to determine the risk factor for each upper limb of each operator (Colombini et al. 2011).

$$Oi = nct \cdot rm \cdot (taf+sf+ip+cr) \tag{2}$$

where:
nct: net cycle time
rm: recovery multiplier
taf: technical action frequence
sf: strength force
ip: incongruous posture
cr: complementary risk
The calculated *Oi* was then checked with the OCRA checklist classes (Table 2) to determine the risk class of each operator. All data were recorded in an IBM/SPSS v.24 spreadsheet and therefore statistically elaborated.

Table 2: OCRA checklist classes and corresponding forecast of ULMSDs (%).

OCRA Checklist score	Risk Classification	Bands	Prediction of pathological risks UL-WMSDs (%)
≤ 7.5	No risk	Green	Less than 5.3
7.6 ÷ 11	Borderline	Yellow	5.3 to 8.4
11.1 ÷ 14	Light	Light Red	8.5 to 10.7
14.1 ÷ 22.5	Medium	Medium Red	10.8 to 21.5
> 22.5	High	Violet	More than 21.5

3. Results and discussion

3.1 The vibration exposure

The vibration total values a_{hv} measured at the two hand positions were very variable and ranged between 15 and 28 ms^{-2} (left hand position) and between 13 and 29 ms^{-2} (right hand position).
The equivalent vibration total values $a_{hv,eq}$ varied between 17 and 27 ms^{-2} (Table 3) and the post-hoc related to the ANOVA test evidenced three similarities among the operators (1, 2 and 4, 3 and 5).

Table 3: Descriptive statistics of the observed $a_{hv,eq}$ data and ANOVA test (p=0.05)

		$a_{hv,eq}$ (ms^{-2})		
Operator_code	Mean	St.dev.	Min	Max
1	25.65	1.49	24.19	27.16
2	18.64*	1.57	16.86	19.84
3	23.38**	1.30	21.92	24.43
4	20.36*	0.81	19.73	21.27
5	23.53**	0.72	22.85	24.29

The daily vibration exposure A(8) of each operator was between 13.3 and 21.5 ms^{-2}, far from 5 ms^{-2} exposure limit value admitted by the European law (Figure 3).
To be coherent with the Directive requirements, in the best case the operator #2 could use the beater for 1 hour and 7 minutes, while in the worst case the operator #1 should use the beater for only 26 minutes. The acquired pictures with the movies revealed also that each operator handled the beater differently. Operator #5, for example, immediately directed the beater head into the canopy losing the hand grip force, while other operators (as the #2) strictly gripped the beater handle also when the sticks were into the foliage. As a consequence, different vibration exposures were obtained, as observed also by other authors (Pascuzzi et al., 2009; Vergara et al., 2008). The different beater handling caused also different upper limb and trunk postures revealed by the OCRA index.

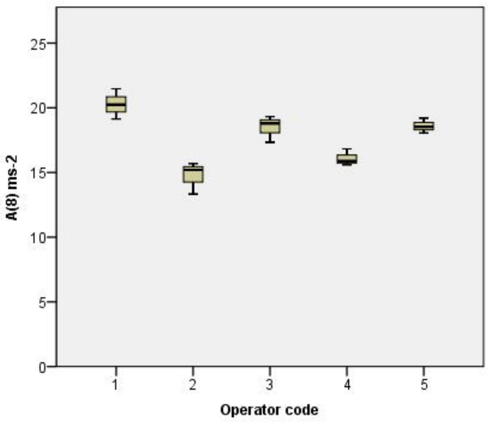

Figure 3: Box-plot of the calculated daily vibration exposure A(8).

3.2 The OCRA index

The OCRA index ranged from a minimum value of 20 (red, medium risk) and a maximum of 32 (violet, high risk) both at the right limb (Figure 4). The right side was the most affected, while for the left limb the same value of 22.20 was obtained for all the operators, because all of them worked with the arms above the shoulders and declared the same strength force. The main contributions to the OCRA index were the number of repeated gestures, the arm lifting above the shoulder, the frequency of the flexion-extension of the elbow and the lack of recovery. Concerning this last factor, Fathallah (2010) proved that programmed breaks may significantly reduce the musculoskeletal discomfort without affecting productivity, also in the agricultural tasks.

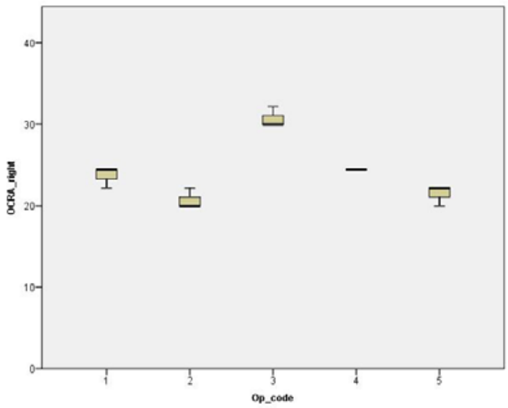

Figure 4: OCRA index at the right arm.

The main concern is however the vibration perceived by the operators: even though beater vibrations are transmitted to both the operators' hand-arms, they did not declare this problem at the right limb, but only at the left, probably due to slightly lower acceleration values registered at the left hand. This misperception of the vibration dose caused the non-calculation of the vibration component at the right upper limb.

4. Conclusions

The olive harvesting with the hand-held beaters is a tiring task, that occurs in not comfortable environmental conditions (sloped terrains, uneven ground, low temperatures) and for many hours per day. Operators are therefore exposed to various risks: among them the risks affecting the upper limbs are among the most serious, because the workers use high vibrating tools in awkward body and arm postures.

In this work the double exposures (HAV and ULMSDs) were investigated and in all the analysed cases both the OCRA scores and the hand-arm vibration values were over the limits allowed by the law. The consequence is an high risk to develop pathologies to the upper limb, which unfortunately appear only after some years and are not well perceived by the workers. It is important to correctly evaluate both the UL-WMSD and the vibration risks caused also by the electric beaters, because in the agriculture sector the related pathologies increased in the last years.

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