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Upper limb disorders and hand-arm vibration risks with hand-held olive beaters

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ABSTRACT

Olive harvesting with hand-held beaters is a repetitive work, tiring and time consuming (more than 4 –5 h/day). Operators work with vibrating tools in not natural body postures: they are therefore exposed to various risks, especially at the upper limbs. Unfortunately, also if in the agriculture sector the number of the declared upper limb disorders increased in the last years, hand-arm vibration and incongruent upper limb postures are not yet well perceived. In this work, the hand-arm vibration exposure and the OCRA index were calculated for five operators which used three different electric olive beaters. In all the observed tests both the hand-arm vibration and the OCRA scores produced results over the admitted limits. *A(8)* ranged between 8.6 ms^{-2} and 25.4 ms^{-2}, far from the 5 ms^{-2} daily exposure limit values admitted by the European law (European Directive 2002/44). The OCRA checklist values ranged from a minimum value of 13.32 (red light level and light risk) for the left limb and a maximum of 34.41 (violet, high level and high risk) for the right limb.

Relevance to industry: This paper describes the analysis of the combined risks to hand-arm vibration and to upper limb disorders in a typical agricultural harvesting task with a manual handled tool powered by electric engine. Tests were carried out during the olive harvesting with five operators using three different hand-held machines. Both vibration and OCRA parameters were acquired. Results showed that in all the observed tests both the hand-arm vibration and the OCRA scores were over the admitted limits. Beaters transmitted vibration to both the operators' hand-arm system, but operators did not declare to perceive vibration at the right upper limb (because it was less affected by the vibration stimulus than the left one). To acquire reliable values for the upper limb biomechanical risk detection it should be necessary to use measured vibration data in field, avoiding personal judgments. When it is not possible to measure the vibration level, the employer should use the machine instruction, where the manufacturer should have written the vibration total value to which the hand-arm system is subjected, if it exceeds 2,5 m/s^2 (European Directive 2006/42). When this information is not available in the machine instruction, the employer may refers to other sources (European Directive 2002/44), as databases provided by government or institutional bodies, including vibration values obtained by research specialists and vibration consultants.

1. Introduction

Manual olive harvesting is a tiring task, usually carried out with machines (beaters) powered by a little engine acting on the head mounted on a light pole and equipped with oscillating carbon fibre sticks. The operator inserts the beater sticks into the tree foliage and the olive pick-up is directly obtained by the impact of the sticks on olives or indirectly by the vibration transmitted to the willowy branches. The target is to harvest the highest number of fruits in the shortest time, without damaging them.

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Whatever is the motor type (pneumatic, electric or internal combustion engine) or head characteristics (flap, hook, beater), these machines have usually a mass varying in a range of 2–10 kg and the electrics are the lightest. The high number of beats per minute (until 1300) causes the fruit detachment from the branches. Some authors (Lavee et al., 1982; Deboli et al., 2014) showed that the average force to detach the olives is around 3 N, with a fruit mass of few grams (olives of *Frantoio* cultivar have an average mass of 3.5 g) (Tsatsarelis et al., 1984): it is therefore necessary to use tools that produce high acceleration levels to remove the fruits.

Deboli et al. (2016) analysed the tip sticks acceleration of different models of electric beaters and they never found values lower than 600 ms^{-2} (not frequency weighted) with a machine mass around 2 kg and a pole length of about 2500 mm. The combination of the machine configuration (low mass, long pole) and the high sticks velocity (never lower than 6 ms^{-1}) therefore produces high vibration total values measured at the operator's hands position. In-field measurements yielded to data around 20 ms^{-2} (Manetto et al., 2012; Calvo et al., 2014; Deboli et al., 2016) with peaks higher than 40 ms^{-2} (Çakmak et al., 2011).

Many authors studied the relationship between hand arm vibration exposure and human response (Gemne, 1997; Lundborg et al., 1998; Bovenzi, 1998; Bovenzi et al., 2000) and they agreed to affirm that the prolonged use of hand-held vibrating power tools could lead to the hand-arm vibration (HAV) syndrome, which can interest the nervous, muscle-skeletal and vascular peripheral structures of the upper limb. For these reasons, the European Directive 2002/44/EC provided to assess daily limits to the vibration exposures of the operators at the workplace, in order to guarantee their health and safety.

Unfortunately, with their high acceleration values, beaters do not achieve acceptable daily vibration values to avoid the operators' hand-arm vibration risk, unless these machines are used only few minutes during the day (very often less than 5–10 min/day to stay under the daily limits admitted by the European Directive).

Calvo et al. (2014) observed that the operators perform about 25–40 approaches per minute to the tree branches with the machine head, usually with the arms over the shoulders for almost all the harvesting time. The frequency of the task, the arm position above the shoulders, the exerted force (the beater must be continuously addressed into the tree foliage and must forcibly hits the branches or olives) and the duration of the work cycle (the daily harvesting time with the beater switched on is never lower than 4–5 h) are factors which may expose the operator to further risks: the upper limb working musculoskeletal disorders (UL-WMSDs). UL-WMSDs include different work-related musculoskeletal disorders (WRMSDs) at neck, shoulder, elbow, hand and wrist, such as epicondylitis, hand-wrist tendon syndromes, carpal tunnel syndrome and continuous strain trauma (Grieco, 1998). Acknowledged risk factors for UL-WMSDs are the high strength, repetitiveness of actions, awkward body and arm postures, deficiency of resting periods (Bao et al., 2006a, 2006b).

In the Member States of the European Union, repetitive strain injuries at the upper limbs were observed in many countries since many years (OSHA, 2000). In 2014 Great Britain showed the highest prevalence rates of UL-WMSDs in manufacturing and construction (HSE, 2015), but also the agricultural sector was not negligible.

Lifting and carrying heavy loads, repetitive and prolonged stooping and forceful repetitive cutting (particularly during the manual harvesting, weeding and pruning) are common tasks in agriculture, especially in smaller farms, quite spread in Italy. In Italy WRMSDs significantly increased in agriculture in the period 2010–2014 and in particular, UL-WMSDs in 2014 represented the 64% of the declared WRMSDs pathologies (Table 1).

A problem in upper limbs disorder detection in agriculture is linked to the variety of tasks entailing biomechanical overload in different work cycles (Occhipinti and Colombini, 2016).

Table 1
WRMSDs types declared in agriculture in Italy (2010–2014).

	2010	2011	2012	2013	2014
Hand-arm vibration	81	76	37	38	52
Lumbar disc herniation	845	932	926	1087	1217
Upper limb biomechanical overload	1221	1732	1718	2176	2289
Total	2147	2740	2681	3301	3558

Source: authors' elaboration from INAIL data.

American and Swedish studies found high percentages of dairy farmers complaining upper extremity injuries (Pratt et al., 1992; Stal, 2000). Crop harvesting also expose the operators to several risk factors to hands, wrists, elbows and shoulders (Meyers et al., 2000; Fulmer et al., 2002; Davis and Kotowski, 2007; Facci et al., 2012). Scapula-humeral periarthritis, epicondylitis and tendinitis of the hand-wrist were found common in the meat processing and in the preserved vegetable packing (Grieco, 1998). Riihimaki (1995) underlined that repetitive movement of hands and wrists in food packing tasks could lead to the hand-wrist tendon syndrome. Upper limb complaints were also common in the tomato growing industry (Palmer, 1996). Walker-Bone and Palmer (2002) detected a further risk factor for hand-wrist disorders in agriculture: hand vibration by hand mechanics agricultural tools. It is moreover well known since the nineties that the manual works with the arms postured above the shoulders may produce significant levels of fatigue even when the strength demand is not high (Wiker et al., 1990). The discomfort increases with prolonged exposure times, for instance when the operator use hand-held olive harvesters for 4–5 h per day (Fig. 1).

There are therefore all the conditions to analyze the operator's double exposure to hand-arm vibration and to the beater handling during the olive harvesting.

There are many significant contributions for the analysis and assessment of repetitive task for the upper limb and for the definition of useful criteria to establish a risk factor (Colombini, 1998),

Fig. 1. Example of operator's posture observed in field during the olive harvesting with the beater.