A review of current studies to evaluate the effort of the hand of the pruner

Romano Elio, Consiglio per la ricerca e la sperimentazione in agricoltura, Laboratorio di Treviglio, Via Milano 43 - 24047 Treviglio (BG) Italy

Camillieri Davide, Caruso Luciano, Longo Domenico, Schillaci Giampaolo, Department DIGeSA, Section of Mechanics and Mechanisation, University of Catania (CT), Via Santa Sofia 100 - 95123 Catania (CT) Italy

Rapisarda Venerando, Occupational Medicine, Policlinico Universitario “G.Rodolico”, via S.Sofia 78, - 95100 Catania (CT) Italy

Abstract

In vineyard cultivation, winter pruning is among the operational phases engaging a significant number of workers and working hours. The widespread use of pneumatic or electric shears allows an improvement in the quality of work, but when labor reaches the greatest intensity, and winegrowers are forced to employ extra staff, there is significant presence of traditional shears. For this, hand pruning falls among those farming operations observed for risk assessment of musculoskeletal disorder from repeated movements.

This assessment is being conducted through the check-list of the OCRA (Occupational Repetitive Action) method that relies on scores related both to the type of gesture and their relative count, while the intensity is assessed through subjective expression of the workers interviewed. Transforming this subjective expression in a quantifiable value has been the subject of studies through the use of a kit of sensors, applied to the handles of the shears, capable of recording the pressure exerted by the fingers of the hand during the act of pruning.

This methodology, repeated on different grapevine cultivars, with different branch diameters, showed a significant correlation with the thesis under comparison demonstrating the ability of the kit to express the amount of effort detectable by the different areas of the hand. In the next future it is expected that greater use of wireless and lightweight equipment will be done to assess worker exposure to musculoskeletal disorders not only in pruning but in all farming operations.

The aim of the present work is to show the main results achieved by the available technologies in order to formulate an objective index for pruning gesture intensity evaluation.

Keywords: Vineyard pruning, forces, electromyography
1 Introduction

Vineyard winter pruning is the manual finishing operation subsequent to the normally mechanized pre-pruning. It is performed by the pruners with scissors, shears and saws. Despite the increasing replacement of such equipment with electric shears, which can significantly mitigate the effort of the operators, there are still many pruners that make use of traditional instruments. These operations, which are marked by fatigue indicators such as high-frequency and stereotypy in the upper limbs, in the long term can cause musculoskeletal risks (WMSDs, Work related Skeletal Muscle Disorders).

For the description and the assessment of the operations involving upper limb potential biomechanical overload, the Occupational Repetitive Action (OCRA) Index, according to EN 1005 - 5 and ISO 11228-3 standards, allows going into the details of the health issues related to individual gestures. The method, proposed in 1996 and at a later stage updated (Cimbolini & Occhipinti, 2005, 2006), on the one hand leads to a highly detailed description of the work process, on the other hand allows to summarize, in an overview of the work, the analysis derived data.

Studies on ergonomics and pruning tool design were aimed at observing the accumulation of stress to the operator (Wakula et al., 2000; Päävinen et al., 2000; Haapalainen et al., 2000). Other researches (Pezzi et al. 2009), carried out evaluating, on different grape cultivars, the pruning shear strength in laboratory using a penetrometer equipped with load cell, showed no differences between the tested varieties.

Studies on skeletal muscle risks from upper limb repetitive movement exposure in manual pruning of the vineyard, showed that there is a variability in the forces developed by hand pruners (Schillaci et al. 2009).

Manual jobs requiring repetitive movements further aggravate the risk factor related to if they are carried out with high grip forces (Seth et al., 1999, Miller et al. 1995).

Evaluating the intensity of grip strength in manual work plays a key role in ergonomic assessment and in the definition of the exposure; furthermore, it can give support in setting up remedial actions in hygienic characteristics of the work. In addition, the knowledge of the physical requirements of a work step is useful to plan rehabilitation programs and to evaluate the complete recovery (with subsequent return to work) after an event compromising the upper limbs (McGorry et al. 2004). For the evaluation of the impact of jobs that require hand operations comparing them to the hours of work and productivity operator. Freund et al. (2002), proposed biomechanical models (and models driven by inputs of measured values during the execution of activities which, despite being very useful, at the same time require significant information to process the estimates. Test benches methods, to assess the maximum voluntary contraction (MVC) during the application of a force, have also been studied to be taken into account; however, they have not yet been supported by documented accuracy of the evaluation of the forces (McGorry et al. 2004).

Kumar et al. (1997) in an inquiry through playback of effort of 20, 40, 60, and 80% of a PTO using a dynamometer, noted a large variance of accuracy of the estimate, and found that the accuracy of the estimate varied according to the level of effort. Works on ergonomics and of pruning tools design were aimed at observing the accumulation of stress to the operator (Wakula et al., 2000; Päävinen et al., 2000; Haapalainen et al. 2000).

Recent research (Romano et al. 2012) studied the characteristics of different grape cultivars of for their resistance to cutting. Laboratory tests, carried out with shears equipped with pressure sensors, showed that each cultivar had its own resistance to cutting and therefore different efforts were required to the hand of the pruners.

The Agricultural Research Council and the University of Catania developed, through OCRA checklist, exposure assessment of pruners in full field conditions, taking into account the ef-
forts subjectively (by means of a questionnaire) and objectively (thanks to sensor equipped shears) expressed by operators.

However, the OCRA method allows to assess the "strength" with different procedures: a) as estimation of external force by means of dynamometers; b) as estimation of internal strength through clinical trials such as surface electromyography, which assesses the electrophysiological degree of muscle activation. Other Recent researches have been aimed at finding methods capable of replacing subjective judgments with objective values of effort relevant to determining the risk indices.

The present study aims at illustrating the path of the investigations already undertaken by the authors on the musculoskeletal risk during grape pruning operations. These studies had the following purposes: 1) measuring the forces exerted by the hand during the cutting of shoots of several grapevine cultivars; 2) deepening, through the OCRA Index, the risk assessment of upper limb repetitive movements exposure using, as the effort values, both mean values obtained by the Borg CR10 scale of a sensor-weighted shear, and subjective values (Schillaci et al., 2010), 3) objectively evaluating the muscular engagement during cuts through electromyographic measurements.

2 Materials and methods

2.1 Evaluation based on OCRA method

OCRA index evaluation activity was carried out in 7 sites, located in the Eastern Sicily, involving the number of 30 pruners for the detection time of 12 hours (Table 1). Measurements were carried out using the techniques of decomposition into elementary steps, noting the timing and modalities of implementation of operations; were also counted the cuts to strain. Following an established protocol, employees were given a questionnaire to detect musculoskeletal disorders warned during the pruning season. In addition to surveys and field observations, it was decided to carry out the work even during the tapings to examine the frequency, stereo and posture.

Table 1: Observed conditions for the evaluation of the OCRA index.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Pl. year</th>
<th>Form pruning</th>
<th>Planting [m]</th>
<th>N. pruners</th>
<th>Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Nerello mascalese</td>
<td>2003</td>
<td>Small tree</td>
<td>0.80 x 1.10</td>
<td>3</td>
<td>shear</td>
</tr>
<tr>
<td>2 Nerello mascalese</td>
<td>1950</td>
<td>Small tree</td>
<td>1.10 x 1.20</td>
<td>3</td>
<td>shear</td>
</tr>
<tr>
<td>3 Nerello mascalese</td>
<td>1984</td>
<td>Spurred cordon</td>
<td>1.20 x 2.10</td>
<td>10</td>
<td>long-handled shears</td>
</tr>
<tr>
<td>4 Nero d'Avola</td>
<td>2000</td>
<td>Spurred cordon</td>
<td>1.00 x 2.20</td>
<td>6</td>
<td>shear</td>
</tr>
<tr>
<td>5 Nerello cappuccio</td>
<td>1997</td>
<td>Spurred cordon</td>
<td>0.90 x 2.00</td>
<td>2</td>
<td>shear</td>
</tr>
<tr>
<td>6 Chardonnay</td>
<td>2003</td>
<td>Guyot</td>
<td>0.90 x 2.00</td>
<td>2</td>
<td>shear</td>
</tr>
<tr>
<td>7 Merlot</td>
<td>2004</td>
<td>Guyot</td>
<td>0.80 x 1.80</td>
<td>4</td>
<td>shear + hacksaw</td>
</tr>
</tbody>
</table>

The work shift was of 7 hours, with a lunch break of 1 hour. For each variety the number of cuts made per minute was recorded to obtain the technical actions per minute. With reference to the tests conducted with the shears, pruning twigs were subjected to cutting tests to record and measure both the forces exerted by the pruner hand and their distributions in the investigated regions of the hand, at varying of shoot diameter and of grape variety. Studying 5 grapevines, two OCRA indexes were calculated and compared: one by using the sensorized shear for force measurement, and the other by processing subjective ratings from pruners. In both cases … values were converted into the Borg scale.
2.2 Evaluation based on sensors kit method

Tests were carried out in laboratory with traditional scissors (single hand operated) on whose handles 5 sensors (Fig.1) capable of detecting the forces exerted by the hand, and the duration of these efforts have been positioned (Schillaci et al, 2009, Romano et al, 2010). The samples collected during the pruning were immediately subjected to the tests by choosing a cutting shear (Stocker Profil 21) interaction with the media in relation to muscle activity (Haapalainen et al, 2000). Measurements were carried out by means of force sensors Force® Flexi Sensors A201 (Tekscan Inc., Boston, USA) based on printed circuit boards. They are flexible and ultra-thin consisting of two layers of film substrate (polyester/polyamide). The end of such sensors was positioned to coincide with the point of contact of the operator's fingers with the shear handles during pruning to investigate the efforts related to the contact point with the handle of three fingers (index, middle and ring ones) plus two palm areas near the thumb.

![Figure 1: Shear equipped with sensors connected to wireless transmitters.](image)

2.1 Evaluation based on electromyography

In the search for an objective and repeatable methodology lies a series of tests with electromyography (EMG). Seven healthy operators, always in the same position, were requested to perform the cutting on shoots collected from vineyards during the winter pruning in laboratory using two different shears. Medical personnel monitored the electromyography and acquisitions were saved for subsequent data processing. Muscle activity was detected by EMG via surface electrodes placed on the skin, above flexor and extensor carpi muscles and peak values of maximum muscular effort as well as the duration of the signal coming from the muscles during the cut were recorded (Figure 2 and 3).

![Figure 2: Clinical tests during cuttings.](image) ![Figure 3: Electromyography during a cutting.](image)
3 Results and Discussions

3.1 Evaluation based on OCRA method

Questionnaire responses and related measurements returned very homogeneous operator ratings with reference to stress perception in different grapevine cultivars, so that it could be possible obtaining a single rating for each cultivar; such trend is coincident with the weighed scores derived from the Borg scale of force values (Table 2). After carefully examining the workstations and selected risk factors (posture, stereo, complementary, rest) in relation to the type of work OCRA indexes were subsequently calculated for each site (Table 3).

Table 2: Comparison of ratings workers and weighted scores

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Case A</th>
<th>Case B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Borg weighted score</td>
<td>Judgment</td>
</tr>
<tr>
<td>Chardonnay</td>
<td>1.82</td>
<td>light</td>
</tr>
<tr>
<td>Merlot</td>
<td>0.99</td>
<td>very light</td>
</tr>
<tr>
<td>Nerello cappuccio</td>
<td>3.13</td>
<td>moderate</td>
</tr>
<tr>
<td>Nero d’Avola</td>
<td>1.91</td>
<td>light</td>
</tr>
<tr>
<td>Nerello mascalese</td>
<td>1.04</td>
<td>very light</td>
</tr>
</tbody>
</table>

3.2 Evaluation based on sensors kit method

The shear tests carried out on shoots with sensorized scissors provided the values of stress strength and duration (Table 4). On the whole, the trial showed a mean force of 14.71 ± 11.27 N and an average length of cut of 0.68 ± 0.62 s.
The cultivar which required the strongest force to be cut was Nerello Cappuccio (23.08 ± 14.42 N), which also required the highest cutting time, 1.15 ± 0.73 s; on the contrary, Nerello Mascalese was the cultivar requiring the lowest force and the shortest cutting time (12.23 ± 8.01 N and 12.23 ± 8.01 s).

Table 4: Values of the strength and cutting operation duration

<table>
<thead>
<tr>
<th></th>
<th>Force [N]</th>
<th>Lenght of cut [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Chardonnay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merlot</td>
<td>7.60</td>
<td>20.10</td>
</tr>
<tr>
<td>Nerello cappuccio</td>
<td>3.20</td>
<td>22.80</td>
</tr>
<tr>
<td>Nero d’Avola</td>
<td>8.70</td>
<td>37.50</td>
</tr>
<tr>
<td>Nerello mascalese</td>
<td>7.00</td>
<td>22.90</td>
</tr>
</tbody>
</table>

3.3 Evaluation based on electromyography

Data collected during the operations conducted in laboratory conditions, after processing, allowed observing the potentiality of the clinical test to read and interpret the effort made by pruners arm muscles when two different shears were tested: these data are shown below in figure 4 and 5 as box plot of strength intensity (N) and time duration of cuts (s).

![Fig. 4 Intensity (N) in all the cuts](image1)

![Fig. 5 Time duration (s) in all the cuts](image2)

It was also developed an analysis of variance in order to statistically highlight significant influences of the factors considered during the test, on the results of muscular effort pointed out by medical records.

The analysis of variance developed over the intensity and duration of the detected peaks during the cuts showed statistical significance for the used type of shears (P-value <0.001) and for the type of branch subjected to shear (P-value <0.01 ). The repeatability of the test was significant. However, it was detected that the operator influenced as well the intensity of the cut, probably because of the effect of peculiar anthropometric values.
4 Conclusions

Musculoskeletal disorders are more likely to occur when, throughout the working shift, there is lack or inadequate distribution of recovery periods and effort repetitions. With reference to the calculated indexes, the one based on sensor equipped shears was found to be lower than the one resulting from pruners answers to questionnaire converted into Borg scale values CR10. As consequence it is advisable to adopt conventional index because of its higher capacity in protecting workers from effort underestimation.

With reference to field tests with sensorized shears on grapevine cultivars, Nerello cappuccino turned out to be the most cut resistant in agreement with pruner perceptions acquired during the interview and with the check list compiled by the working group for the musculoskeletal disorder risk assessment.

Electromyography acquisitions highlighted the intensity connected to the muscles specifically involved in cutting operations providing new insights into the risk assessment of pruning and suggesting that further work should be carried out in order to deepen the role of the anthropometric factors to better assess the weight of upper limbs morphology on clinical trial results.

In the yards of pruning examined the assessments carried out show that the dominant limb that holds the scissors and cut backs are at risk of exposure. To affect the likelihood skeletal muscle, as well as the frequency and posture, are essentially the lack or inadequate distribution of periods of recovery, and the repetition of the effort, throughout the duration of the work shift.

With regard to the indices calculated with the two different methods of evaluation of the forces, the index calculated with the value of the shear forces measured with sensor-supplied values less than that calculated using the ratings pruners, expressed in Borg scale values CR10. For this reason it may be prudent to use the conventional index, that protects workers from underestimation of the effort.

As expected from the CV Nerello cappuccio, is still the most resistant to cuts in agreement with the submissions of the pruners during the interviews in terms of exertion and perceived with what is reported in the check list compiled by the working group for the assessment of risks muscle skeletal.

Results from electromyography tests have highlighted the involvement of affected muscle groups, providing new insights into the risk assessment of pruning. In particular, the results suggest further study with evidence of a greater number of operators evaluating the effect of anthropometric factors to assess the weight of clinical trial results of the morphology of the upper limbs.

5 Acknowledgements

This work was carried out within the framework of the “INTRAC” project, funded by the Italian Ministry of Agriculture and Forestry. Authors also acknowledge Mr. Elia Premoli (CRA-ING, Laboratory of Treviglio) for his valuable help in setting up the experimental facility as well as the preparation of materials and the data collection.

6 References


