Assessment of the "Strain" Parameter in the Calculation of the Biomechanical Risk Index as Regards the Upper Limbs in Vineyard Manual Pruning

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Abstracts
Vine pruning provokes strain (*Schillaci et al.*, 2009, *Montomoli et. al.*, 2008). Moreover the need to develop force repetitively and with a high frequency has been noted in the literature as a risk factor in causing pathologies in the tendon and muscle structure.
The force is usually estimated on the Borg CR10 scale, which is used to assess the subjective perception of the effort in relation to the force itself.
The aim of the research was to assign numerical values (derived from cutting trials using sensorised secateurs) to the effort necessary to carry out pruning and to verify whether the results obtained are comparable with the workers' subjective perception of the effort. As regards the subjective assessment of force used, a questionnaire on perception of effort made was given to a sample of pruning operators at the end of the experiment. The judgements were then converted into a score on the Borg CR10 scale and subsequently the average force score was calculated. The numerical values of the force were derived from cutting trials using sensorised secateurs carried out on various vine cultivars (*Schillaci et al.*, 2010) and processed with software R for statistical elaboration. They were also compared with the maximum force capacity limit values provided by the international standard EN 1005-3. The calculation simulations of exposure taking into account the objective values of the force were carried out with the software "midaOCRAmulticompiti". The replies to the questionnaire were very homogeneous as regards the operators' perception of the strain involved for the various vine cultivars.The force values derived were compared with the corresponding limit value of maximum force capacity (EN 1005-3). From the numerical values of the force and respective duration the weighted average force value (%) and weighted Borg score were calculated. From the comparison of the operators' assessment of the strain with the respective weighted scores, it appears that the latter are lower, that is to say that the values to be attributed to the strain in the Ocra Index may be lower.

Keywords: OCRA, WMSDs, force, dynamometric shears

Introduction
Vine pruning provokes strain (*Montomoli et. al*., 2008, *Schillaci et al.*, 2009, 2010,). The need to develop force repetitively is recorded in the literature as a risk factor in causing pathologies in the tendon and muscle structure (Silverstein et al. 1986; 1987).
The force developed during the movement is defined as the biomechanical effort required to carry out a specific action or sequence of actions. It can be dynamic (applied directly by the operator for the execution of the action), or static (holding work tools or keeping single segments of the arms in a determinate position) (*Colombini et al*., 2005).

For the assessment of the risk involved in repetitive movements of the upper limbs with the OCRA Index (*Colombini e Occhipinti*, 1996; 2005), the force is usually estimated by means of the Borg CR10 scale, which is used to evaluate the subjective perception of the strain in relation to the entity of the strain itself.
The aim of this work was to attribute numerical values – derived from cutting trials with sensorised secateurs - to the strain necessary to carry out pruning and to assess whether the results obtained are comparable with the workers' perception of the effort. This would make it possible to establish whether it might be convenient to substitute measured values, weighted on the Borg scale, for subjective opinions.

Materials e methods
The evaluation of the forces focussed on the cutting of shoots of 5 cultivars that are widespread in eastern Sicily: Chardonnay, Merlot, Nerello cappuccio, Nerello mascalese e Nero d'Avola.
Besides field observations, for the subjective assessment of the force used, a questionnaire about the perception of the strain involved in making the cuts was administered to twenty pruning operators at the end of the observation period. The operators gave verbal rather than numerical answers (for example slight, moderate, etc) for each cultivar considered.
The verbal replies were then converted into a score on the Borg CR10 scale and the average score relative to the force was calculated.
The numerical values for the force were obtained from cutting trials carried out with traditional secateurs, which had had five sensors applied to their handles. Thanks to the sensors, the forces exercised by the hand and the duration of this strain could be ascertained (*Schillaci et al*., 2009, 2010).
The values obtained were compared with the limit value of maximum force capacity provided by the EN 1005-3 international standard (*Colombini et al.*, op cit). Regulation EN 1005-3, *Recommended force limits for machinery operation*, describes a method for calculating maximum force capacity limits (F_L), which can be carried out during the use of mechanical equipment, taking into consideration the various types of action and the characteristics of the target population. This value is obtained by starting with the values calculated for various activities carried out by the target population and then multiplying by a series of coefficients (*mv, mf, md*), which take into account the speed, frequency and duration of the activity.
The calculation of risk simulations using the force values measured were carried out with the software "midaOCRAmulticompiti" (Colombini e Occhipinti, 2005).
Values refer to the average of the distribution of forces among five regions of the hand.
Limits to the present work include the fact that the values for the force exercised by the hand were derived from laboratory and not field trials and that these trials involved staff not used to carrying out the work.

Results
From the observations and the questionnaire, very homogeneous answers were obtained regarding the operators' perception of the strain involved in pruning the various vine cultivars and it was possible to derive a single assessment for each cultivars and the corresponding value on the Borg CR10 scale (Tab.1).

Tab.1 – Strain assessments

Cultivar	**Assessment of strain**	**Borg value**
Nerello cappuccio	moderate	3.5
Nero d'Avola	Slight-moderate	2.5
Chardonnay	slight	2
Merlot	slight	2
Nerello mascalese	slight	2

The table below (Tab. 2) shows the mean force values and mean strain duration values obtained from the cutting trials using sensorised shears.

Tab. 2 – Force and duration values

	Force [N]				**Duration [s]**			
	Min	Max	**Mean**	St. Dev.	Min	Max	**Mean**	St. Dev.
Nerello cappuccio	9.00	37.50	**23.25**	14.25	0.45	1.90	**1.20**	0.75
Nero d'Avola	7.00	23.00	**15.00**	8.00	0.40	1.10	**0.75**	0.35
Chardonnay	7.50	20.00	**13.75**	6.25	0.20	1.20	**0.70**	0.50
Merlot	3.50	23.00	**13.25**	9.75	0.25	0.70	**0.47**	0.22
Nerello mascalese	4.00	20.50	**12.25**	8.25	0.17	0.62	**0.40**	0.22

The maximum capacity of force (F_L) for a task characterised by the thumb opposing the other fingers of the hand (typical when secateurs are gripped), and by rapid high frequency movements for the entire work shift was found to be 30 N. The value was obtained with the formula:

$$F_L = F_b \times mv \times mf \times md$$

where F_b = 250 N, *mv* = 0.8, *mf* = 0.3, *md* = 0.5 (EN 1005-3).
With reference to the same regulation, the simple movement of the limb holding the secateurs was assigned a value equal to 5% of the F_L, as it was not considered an action requiring force.
Table 3 shows the percentage level of the derived values with respect to the limit value of maximum force capacity of 30 N.

Tab. 3 – Level with respect to F_L (%)

	Min	Max	Mean
Nerello cappuccio	30	125	78
Nero d'Avola	23	77	50
Chardonnay	25	67	46
Merlot	12	77	44
Nerello mascalese	13	68	41

As regards the weighted force value with respect to the corresponding F_L limit value and the weighted mean score using the Borg CR10 scale, table 4 shows, as an example, the calculations relative to the cultivar Nero d'Avola, considering the average time necessary to prune a plant to be 24 seconds (*Schillaci et al.*, 2009) and using the mean force value.

Tab. 4 – Calculation of the weighted mean strain value and the force capacity required - F_L (%).

		A	**B1**	**B2**	**A x B1**	**A x B2**
	Sub-division of 24-second time cycle	Sub-division of % force level in time	% level with respect to FL	Borg scale score	Weighted force value (% FL)	Weighted Borg score
Mean Force	cuts = 7.5 s	31	50[1]	5.00[2]	15.63	1.56
	Limb movements = 16.5 s	69	5[3]	0.50[4]	3.44	0.34
	TOT = 24 s	**WEIGHTED MEAN SCORE**			19.06	**1.91**

[1] B1 = (mean force value x 100/ F_L) = 15 N x 100/30 N = 50
[2] B2 = B1/10 = 50/10 = 5
[3] B1 = 5% of F_L
[4] B2 = B1/10 = 5/10 = 0.5

The graph below (*Fig. 1*) shows the weighted Borg scores, relative to the mean strains for the 5 cultivars under consideration.

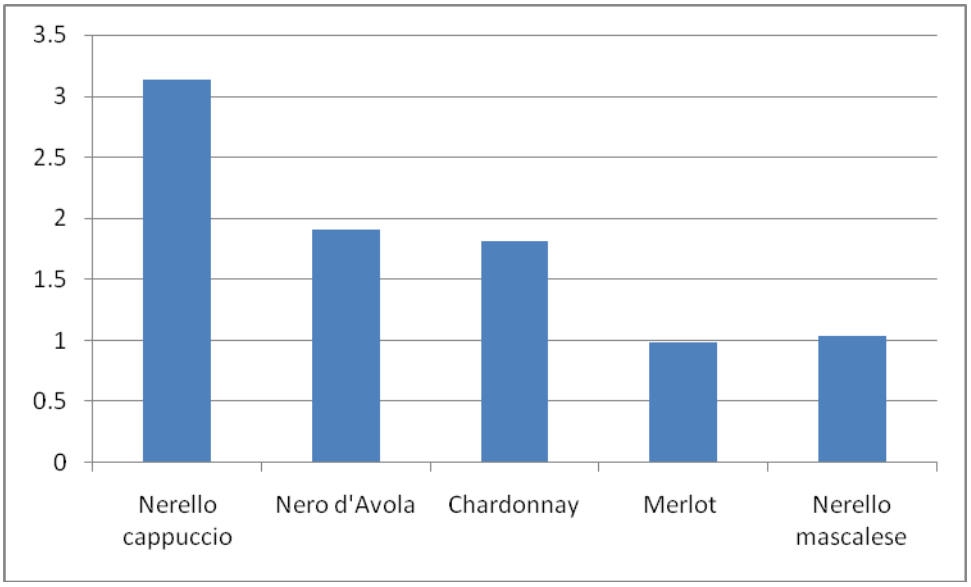

Fig. 1- weighted Borg scores for the 5 cultivars

From the calculations it can be seen that the weighted Borg scores and those derived from the workers' assessments have similar trends.
The values of this scale were compared with the workers' assessments.

Tab. 5 – Comparison of workers' assessments and the weighted scores

Cultivar	Operators' assessment Borg value	Weighted Borg score	Assessment
Nerello cappuccio	moderate 3.5	**3.13**	**moderate**
Nero d'Avola	Slight-moderate 2.5	**1.91**	**slight**
Chardonnay	slight 2	**1.82**	**slight**
Merlot	slight 2	**0.99**	**very slight**
Nerello mascalese	slight 2	**1.04**	**very slight**

From the comparisons it can be seen that the weighted assessments are lower than the subjective ones, that is to say that the cut in itself seems to be less onerous than reported by the operators in the questionnaire. This can be explained by the fact that the operator tends to over-estimate the muscular strain because he confuses it with the general tiredness he feels while carrying out the work. This tiredness depends both on a series of factors that characterise the work itself (not only the force required, but also the work environment, equipment, work rhythms and times, etc) and on the work context (organisation, motivation, personal relationships in the work place, etc.).
Figure 2 (below) presents the Ocra Indices relative to the 5 cultivars calculated with the strain values obtained from the operators' assessments (Ocra Index A) and the strain values derived from cutting trials using sensorised secateurs (Ocra Index B).

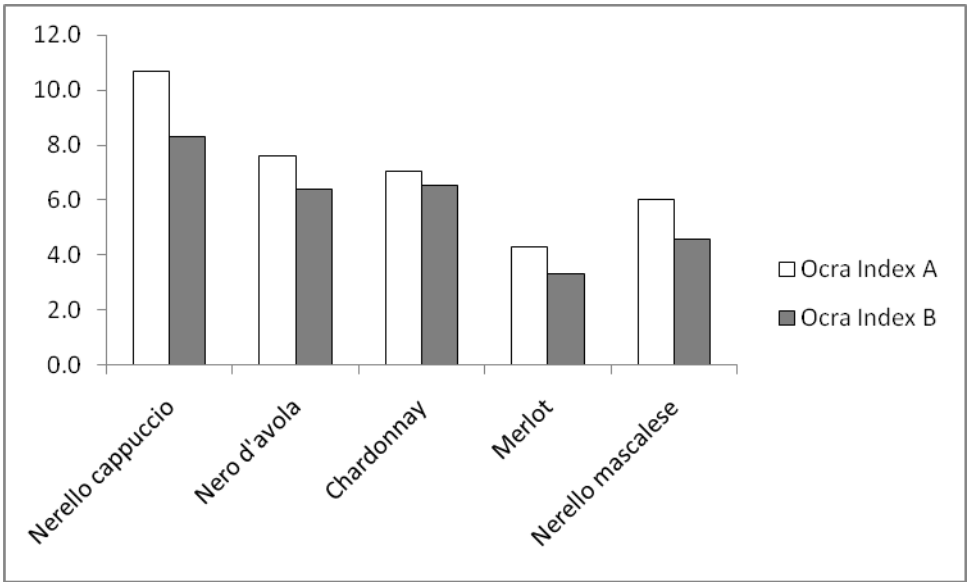

Fig. 2 – Results of Ocra Index Simulations

Ocra index B is, on average, 18.4% lower; the smallest drop (7.1%) occurred in the case of Chardonnay; the most significant difference (23.5%) was found for Merlot and Nerello mascalese – here the drop in the index coincides with a reduction of risk from medium to low. As regards Nerello cappuccio the index difference is 22.3%, taking the risk from high to medium.

The most representative bracket is the medium red one, where there is a medium exposure risk. Given the risk in this bracket, a percentage of pathological cases (number of subjects suffering from 1 or more diagnosed UL-WMSDs per 100 workers at risk) between 10.76 and 21.51% could be expected (*Colombini et al.*, op cit).

Conclusions and prospects

The values measured in the cutting trials carried out with sensorised secateurs were converted into weighted Borg scores relative to the average strains for 5 cultivars with the procedures and limits required by the method. It can be confirmed that Nerello Cappuccio requires the use of the greatest force, followed by Chardonnay, Nerello mascalese and Merlot, indicating reasonable correspondence between the methods.

From the comparison of the operators' assessment of the strain with the respective weighted scores, it appears that the latter are lower, that is to say that the values to be attributed to the strain in the Ocra Index may be lower.

In fact, simulating the calculation of exposure to risk with respect to the strain values obtained from the assessments of the operators (Ocra Index A) and the strain values derived from the cutting trials (Ocra Index B), the latter was found on average to be 18.4% lower.

To establish whether the subjective assessments should be substituted by the measured values weighted on the Borg scale, a further study on the number of cases actually diagnosed and the percentage of pathological cases estimated should be carried out as this would give more information about the strain and in particular establish whether there are significant differences between the number of diagnosed cases of upper limb disorders and the number foreseen by the Ocra model calculated with both subjective and measured strain values.

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