The Effect of Task Frequency on Risk of Biomechanical Overloading of the Upper Limbs in Manual Pruning in Vineyards

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Abstract

Among the factors affecting the risk of biomechanical overloading of the upper limbs, repetitiveness is certainly the most important. In manual pruning of vineyards repetitiveness is closely linked with the frequency of cuts and technical actions in unit time. The aim of the research was to assess the interaction between independent variables (tool used for pruning, vine cultivars pruned, work times) and the variable dependent (cut frequency). The data collected made it possible to extract the representative frequency for time periods and calculate the Ocra Index for each period, to compare the results obtained with the index calculated on the basis of the average daily frequency and, finally, to trace the progress of the work productivity curve during the day. The action frequency was evaluated with analytical counting of the technical actions by re-examining video films of the work in slow motion. Statistical analyses were carried out with the publicly available software R. Statistical analysis of cut frequency was carried out using data collected from 18 pruning operators. Two tools (traditional shears and long handled hacksaws), three cvv (Nero d'Avola, Merlot, Nerello mascalese) and three different time periods were considered. Eight repetitions were carried out for each pruning operator. The influence of the above factors was extrapolated by means of variance analysis (ANOVA). Subsequently, given the highly significant results for the first and second order interactions, in two pruning sites (traditional shears and long handled hacksaw) the respective daily work productivity curves of the workers were found, further sub-dividing the work day into thirty minute periods. The analyses confirm the great significance of the interaction of the independent variable, even if it cannot be seen which of the variables is the most significant. The workers' work productivity curves depends not only on the characteristics of the site (species and growing method, tool used for pruning, etc) but above all on the tiredness of the operator, which varies during the day, following a sinusoidal curve similar to that found in other work sites (CNR, 1981).

Keywords: OCRA, WMSDs, vine cultivation, productivity

Introduction

Among the factors affecting the risk of upper limb biomechanical overloading, which can, in time, provoke damage to the muscular-skeletal system (*WMSDs*, *Work related Muscolo Skeletal Disorders*), repetitiveness is the most important (*Colombini et al.*, 2005).
From recent studies (*Regione del Veneto*, 2008) it would seem that there is evidence of an association between repetitiveness of gestures and upper limb pathologies, above all those affecting the neck, shoulder and hand wrist system. There is no certain evidence that the elbow is affected.

Traditional literature defines as repetitive work characterised by cycles lasting less than 30 seconds (2 cycles/minute) or when 50% of the work time, irrespective of duration, is spent carrying out the same gesture or sequence of gestures (*Silverstein et al*., 1986, 1987).
Repetitiveness is, therefore, closely connected to action frequency, that is to say the number of technical actions in unit time (actions/minute). By technical action what is meant is an action involving mechanical activity that can be identified with a set of movements (of one or more segments of the upper limbs) that permits the carrying out of an operation aiming at a pre-determined operation, and not a single gesture or single biomechanical movement (*Colombini et al.*, 2005).
In manual vineyard pruning, which is characterised by exposure to risk, the repetitiveness is closely linked to the frequency of cuts and the associated technical actions (*Montomoli et. al*., 2008; *Schillaci et al.*, 2009, 2010).
The aim of the research was to assess the effect of the factor frequency on the calculation of upper limb skeletal-muscular risk. Once the variability of frequency (hourly productivity) had been calculated for different periods of the day, the Ocra Index was calculated with the weighted mean frequency and this was compared with the value calculated with the mean daily frequency.

Materials and methods

The manual pruning was broken down into basic components (C.I.O.S.T.A. - A.I.G.R. methodology), this also revealing times and methods of operation executions.
The technical actions and the frequency of gestures were assessed both in the field and by re-examining the video films of the work in slow motion. The statistical analysis was carried out by means of the publicly available software Assistat ed R.
The data was collected from a sample of 18 professional pruners, with 8 repetitions for each of them. The factors taken into consideration were: the two tools used (traditional secateurs and long handled saw, the three cultivars (Nero d'Avola, Merlot, Nerello mascalese) and the three different time slots (7÷9 - 9÷11 - 12÷15). The influence of the factors was extrapolated with variance analysis (ANOVA).
Once the normal distribution of the frequencies found in the field had been evaluated and the factors influencing them highlighted, the Ocra indices were calculated and the daily productivity curves traced.
The Ocra indices were calculated for two pruning sites – one using traditional secateurs and one using a long-handled saw. For each site the indices were calculated with the mean daily frequencies and the mean frequency for time slots, dividing the working day (7 p.m. ÷ 3 p.m.) into hourly periods. The strain value was obtained from the opinions expressed by the pruners and a recovery time suitable for every hour of work was considered. The calculation only took into consideration the dominant limb, which is the one most exposed to tiring.
The daily productivity curves were found for both sites, further sub-dividing the working day (7÷15 p .m.) into thirty-minute periods.

Results
Frequency analysis

1) Normality finding.

Tab. 1 – Normality analysis

NORMALITY (a = 5%)				
Test	Value	Vkrit	p-value	Normal
Kolmogorov-Smirnov (D)	0.07699	0.10437	p > .15	Yes
Cramér-von Mises (W2)	0.05546	0.12513	p > .15	Yes
Anderson-Darling (A2)	0.36470	0.74900	p > .15	Yes
Kuiper (V)	0.12350	0.17250	p > .15	Yes
Watson (U2)	0.04911	0.11520	p > .15	Yes
Lilliefors (D)	0.06310	0.10442	p > .15	Yes
Shapiro-Wilk (W)	0.98099	0.34772		Yes

The analyses carried out with the tests indicated in table 1 gave the normal distribution of the data collected and this enabled adaptation to a linear model for the ANOVA test.
The distribution of the data for the mean cut frequency (*Fig. 1*) was 23.40 cuts/min (σ = 4.76).

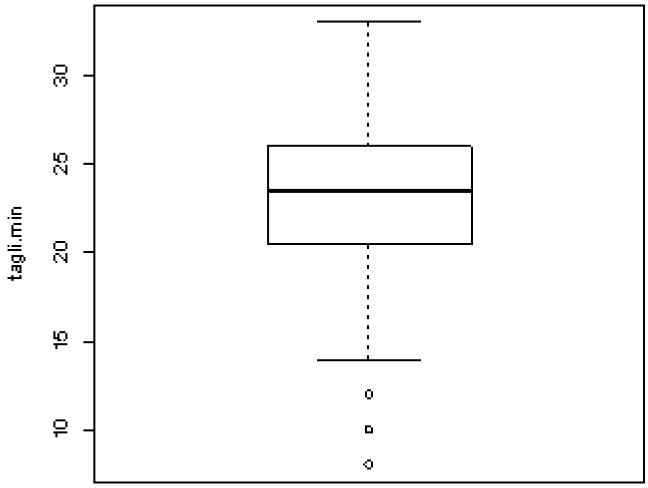


Fig. 1 – Distribution of mean frequency data

2) ANOVA analyses.
The aim of the analyses was to establish the significance of the independent variables (tool used for pruning, cultivar pruned, time of work) on the cut frequency effect (dependent variable).
From the analyses it emerges that all the factors considered have great statistical significance. The repetition (*Fig. 2*) does not have significance and hence the experiment shows great repeatability.
The mean frequencies found for the instruments (*Fig. 3*) were 22.57 cuts/min (σ = 4.88) for the secateurs and 25.88 cuts/min (σ = 3.43) for the shears.
The mean frequencies found for the cultivars were 24.58 cuts/min (*Fig. 4*) (σ = 4.88) for Nero d'Avola, 20.00 cuts/min (σ = 6.20) per Merlot and 24.50 cuts/min (σ = 3.47) for Nerello mascalese.

The mean frequencies found for time periods (*Fig. 5*) were 24.06 cuts/min (σ = 5.51) for time period 7÷9, 21.53 cuts/min (σ = 4.02) for time period 9÷11 and 25.87 cuts/min (σ = 3.58) for time period 12÷15.

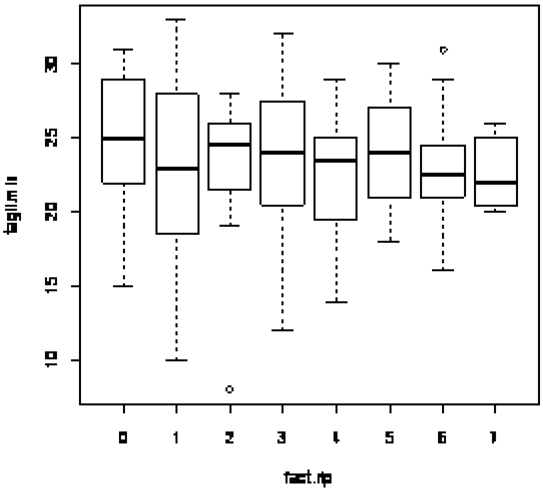


Fig. 2 – Mean frequencies for repetitions

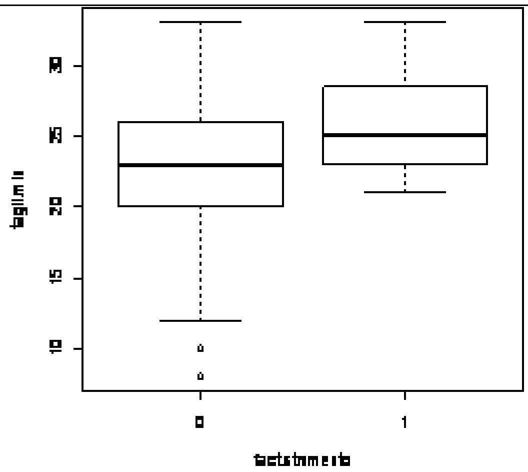


Fig. 3 – Mean frequencies for tools

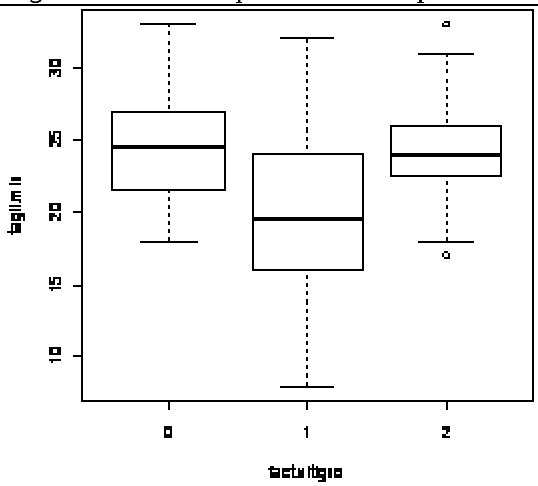


Fig. 4 – Mean frequencies for cultivars

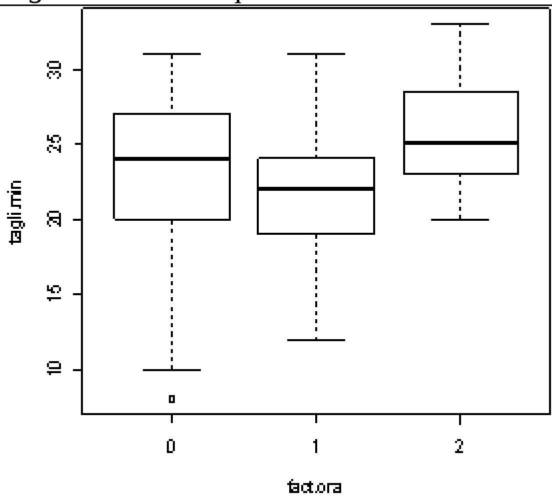
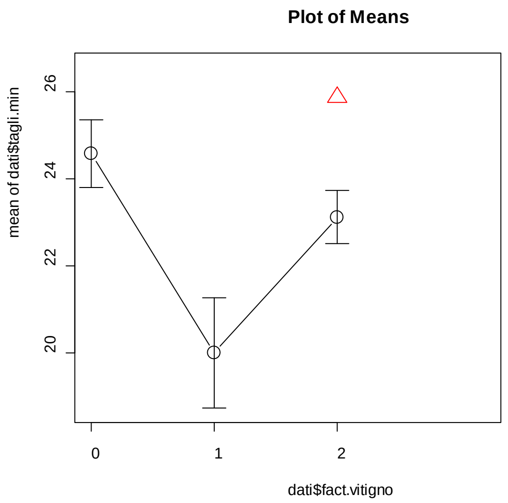


Fig. 5 – Mean frequencies for time periods

3) Execution of multiple comparison tests to show differences between the means. From the Tukey test on data from the cut carried out with shears performed with an experimental design is a factor analysis, it can be seen that the cultivars Nero d'Avola and Nerello mascalese cause a similar effect, while the frequency for the cultivar Merlot seems to be much lower (*Fig. 6*). As regards work periods, the times 7÷9 - 9÷11 have a similar effect while the third time period, after the lunch break, has a different effect (*Fig. 7*).

4) Execution of Tukey test on data sample from completely random experiment. From the Tukey test carried out on data samples from the two instruments to be compared, conducted with an experimental design and completely random experiment, it was found that the cases analysed (12 in total) gave similar values, but that three results are noticeably lower than the others. These all regard the use of secateurs in the second time period (9÷11) for all three cultivars.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On the "secateur" site, the daily exposure index is 4.1. On the "saw" site the daily index is 4.5. In both cases the index can be considered to belong to the 'slightly red' belt, ie to a slight exposure risk.

Productivity indices

The productivity indices were calculated for both sites (Tabs. 4 and 5). These were derived from the relationship between the hourly productivity and the mean daily productivity (CBR, AA.VV.,1981)

Tab. 4 – Pruning work productivity in "secateur" site

		Productivity	**Mean productivity**	**Producvity index**	**Difference**	**Ocra Index**
Time period		cuts/(h*op.)	cuts/(h*op.)	%	%	
7	7.30	1185	1342	88.27	-11.73	3.6
7.30-	8	1440		107.26	7.26	4.4
8	8.30	1635		121.79	21.79	5.0
8.30	9	1605		119.55	19.55	4.9
9	9.30	1485		110.61	10.61	4.5
9.30	10	1410		105.03	5.03	4.3
10	10.30	1200		89.39	-10.61	3.7
10.30	11	735		54.75	-45.25	2.2
11-12		Break				
12	12.30	1020	1342	75.98	-24.02	3.1
12.30	13	1365		101.68	1.68	4.2
13	13.30	1560		116.20	16.20	4.8
13.30	14	1500		111.73	11.73	4.6
14	14.30	1350		100.56	0.56	4.1
14.30	15	1305		97.21	-2.79	4.0

Tab. 5 – Pruning work productivity in "saw" site

		Productivity	Mean productivity	Productivity index	Difference	Ocra Index
Time period		cuts/(h*op.)	cuts/(h*op.)	%	%	
7	7.30	1290	1461	88.27	-11.73	3.9
7.30-	8	1350		92.38	-7.62	4.1
8	8.30	1560		106.74	6.74	4.8
8.30	9	1530		104.69	4.69	4.7
9	9.30	1620		110.85	10.85	4.9
9.30	10	1440		98.53	-1.47	4.4
10	10.30	1470		100.59	0.59	4.5
10.30	11	1410		96.48	-3.52	4.3
11-12		Break				
12	12.30	Break				
12.30	13	1110	1461	75.95	-24.05	3.4
13	13.30	1380		94.43	-5.57	4.2
13.30	14	1710		117.01	17.01	5.2
14	14.30	1440		98.53	-1.47	4.4
14.30	15	1560		106.74	6.74	4.8
		1590		108.80	8.80	4.8

From the values obtained the curves representing the work productivity in both sites were drawn up (*Figs. 8 and 9*).

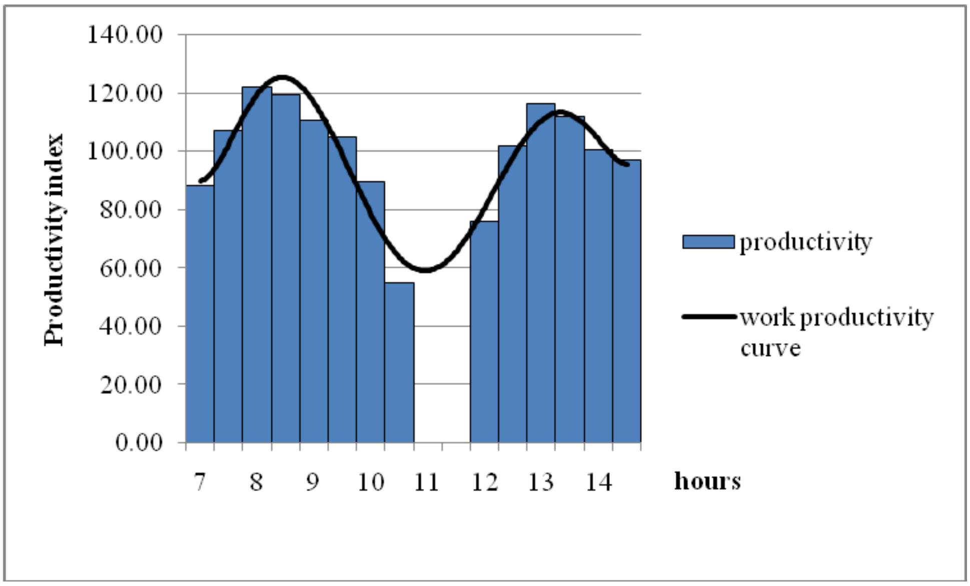

Fig. 8 – "Secateur" site – Work productivity curve

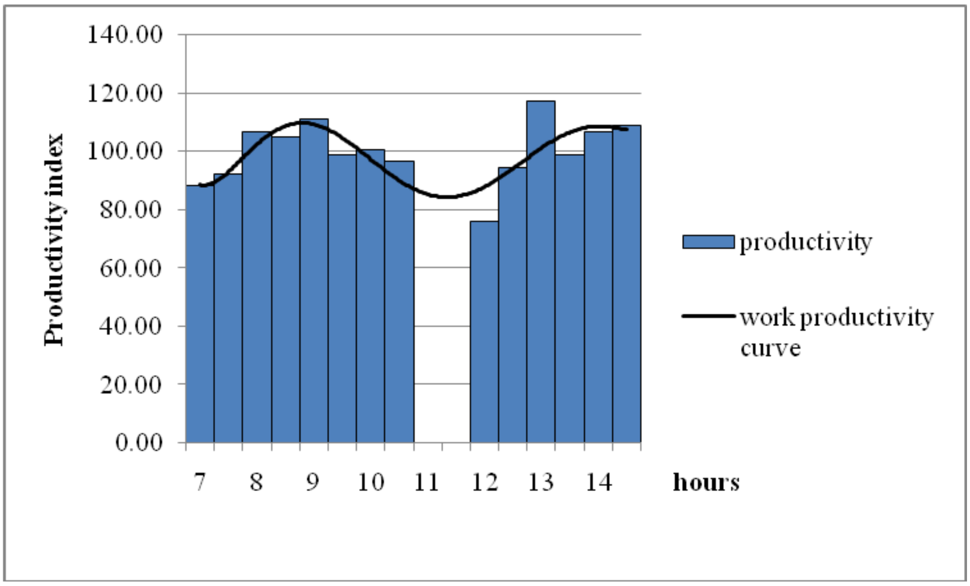

Fig. 9 – "Saw" site – Work productivity curve

Looking at both the pruning sites, it can be seen that the mean productivity is higher for the "saw" site, with , on average, 119 cuts more per hour (about 2 per minute).
On the "secateur" site greatest productivity is reached between 8-9 and the curve shows two peaks corresponding the 8-9 and 13-14 time periods. There is least productivity between 10-11 after three hours of work and just before the lunch break. In fact between 10.30 and 11 there is a 45.25% reduction in productivity.
On the "saw" site the greatest productivity was found in the 13-14 time period and the curve shows two peaks corresponding to the 9-10 and 14-15 time periods. There is least

productivity between 12-13, just after the lunch break. In fact between 12 and 12.30 there is a 24.05% drop in productivity.
The following graphs show a comparison of the Ocra indices using the mean frequencies for the time periods with respect to those calculated using the daily mean frequencies (figs. 10-11).

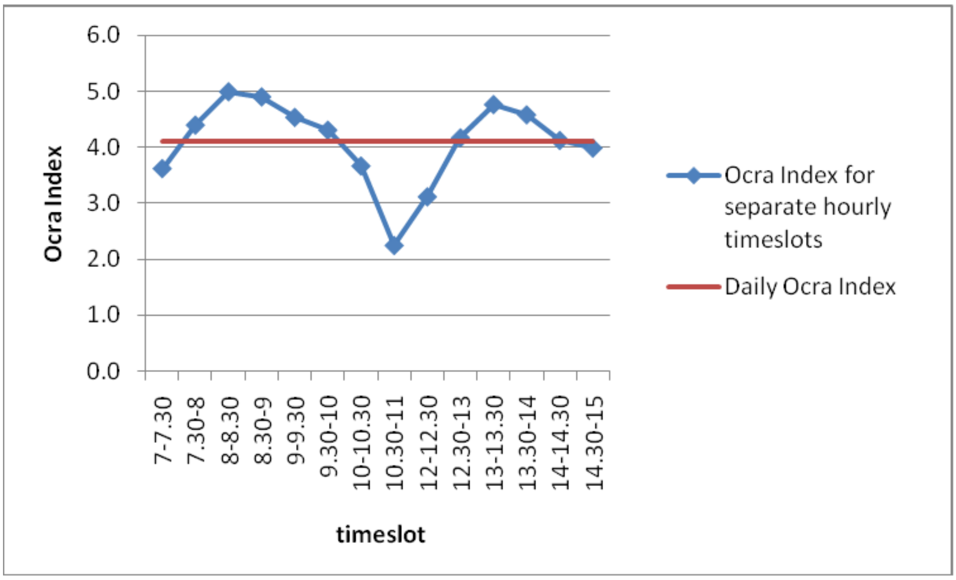

Fig. 10 – "Secateur" site – Trend and comparison of indices

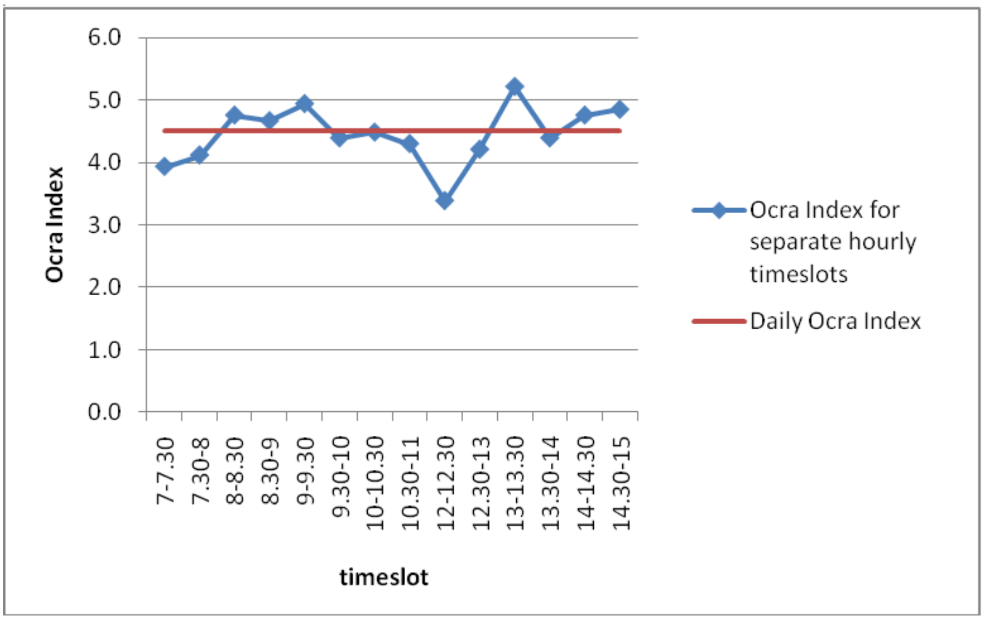

Fig. 11 – "Saw" site – Trend and comparison of indices

On the "secateur" site the half hour time period frequency findings show that for 57% of the daily working time the respective Ocra Index is higher than the Ocra Index calculated looking at the mean daily frequency (4.1). Moreover, it should not be overlooked that for a time period of little less than 30% of the working day, the index is in the upper risk bracket

(average risk, from 4.6 to 5.0), while for about 15% of the work time – around the lunch time – the risk fell to borderline – 2.2-3.7.
On the "saw" site, for 43% of the daily working day, the Ocra Index calculated for time periods is higher than the mean daily Ocra Index (4.5). For all of this period the higher risk bracket is reached as the daily mean is at the limit between minimum and average exposure. For about 7% of the work time – in the half hour after the lunch break – the Index drops to a lower risk bracket (borderline).

Conclusions e prospects

This preliminary analysis has shown that the frequency data come from a normal population. The ANOVA analysis has shown the great significance of the variable independents (tools used for pruning, cultivar pruned, work times) on the cut frequency. As regards the cultivar, the cut frequency seems to change most for Merlot, particularly when Guyot pruned. In the case of pruning with secateurs, regardless of which cultivar is considered there was a drop in work frequency in the second time period (9-11).
Starting with frequency, productivity was calculated and a curve with an undulatory trend was found – similar to that found by other authors working on citrus fruit harvesting. The curve can be used to better identify breaks for diminishing tiredness and reducing the Ocra Index. Studies carried out about citrus pruning or flowers harvesting have shown good effects of a break at almost 2.5 – 3 hours from the beginning of the work and a second one at 2 – 2.5 hours from the first one; future work will examine if similar effects can be obtained also in wine winter pruning.
Our studies show that starting at 7 o'clock in the morning, the lower exposition to biomechanical overload runs from 10 and 13 o'clock. That circumstance is more evident if operators use secateurs.
As concerns wine winter pruning, calculating Ocra index per each hour or per short time slots enhanced a potentially dangerous underestimate that could occurs when we used the daily average value. When we carry out studies about agricultural activities, in which frequency can varies consistently throughout the day, that circumstance must be take in account to preserve health and safety of workers.

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