First Results of a Comparative Study on Biomechanical Overload with Different Tools for Pruning Through Vocational EMG Analysis

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Abstract
Starting from these first studies on hazard and damage produced by biomechanical overload of wine-growers' and olive-growers' upper limbs, musculoskeletal disorders of these areas are assumed to be also correlated with the use of inappropriate pruning equipment. The paper is aimed at facing a preliminary feasibility analysis of future studies on working tools used in agriculture in order to search those better meeting ergonomic criteria in view of obtaining "ergonomic quality brands". Second goal is using an exportable instrumentation for surface electromyographic analysis on the field during design of new models to check their accuracy ever since the beginning.

Keywords: surface elecrtromyography, force; muscular fatigue, work related muscle skeletal disorders, biomechanical overload, ergonomic redesign

Introduction and goals

The present research is aimed at identifying the parameters indicating the muscular activation levels by analysing the surface electromyographic signal recordable during a dynamic manual work. Such parameters would be able to provide more objective information essential for ergonomic design of tools and workplaces as well as for risk assessment of upper limb musculoskeletal disorders (UL-WMSDs) associated with a specific activity.
A typical problem of agricultural work is the prolonged and rapid used of scissors for pruning. This prolonged use may be the origin of a variety of musculoskeletal disorders affecting hand, wrist, elbow and shoulder. Some kinds of pruning tools were selected to assess necessary muscular activation levels.

Methods

After carefully going through the literature on acquisition and processing surface electromyographic data from an ergonomic standpoint, a new apparatus and new procedures were implemented for synchronized EMG and video acquisition, ensuring a good inter and intra subjective repeatability degree and a processing software for technical use "on the field" to calculate signal frequency and width parameters, regarding fatigue and muscular force respectively was implemented.
The developed methodology was first tested in laboratory on a group of healthy subjects, studying a "pick and place" repetitive task.
The methodology was then tested in a working environment to evaluate applicability in analysing the working gesture also under non-controlled conditions like those of a laboratory, in particular to compare the muscular effort required during the use of different types of tools for pruning.

Applicative protocol at workplace

Seven types of tools (two manual, four pneumatic and one electric scissors) were used during branch cutting olive trees of 0.4 to 1.5 cm size, by two skilled subjects: one 42 year woman and one 50 year man with 156 height and 54 weight the former and 172 cm height and 95 kg weight the latter, respectively). Selection was based on subjects with no neuro-muscularskeletal diseases.
The goal was assessing EMG data acquisition and processing method effectiveness in differentiating muscular activation levels recordable using the different tools to be able to draw conclusions on the best ergonomic tool in terms of upper limb biomechanical overload reduction during pruning stages.

Data acquisition

Each subject was submitted to test preparation experimental stage (subject preparation, execution of maximum voluntary contractions of each muscle involved in the analysis).
Then, each subject made a cutting test of 30 s duration with each pruning tool cutting branches with three different diameter sizes here below indicated as "small" (between 0.4-0.,6 cm), "medium", (between 0.6 and 0.8cm), and "large"(between 0.8 and 1.5 cm). Details of tests and tools are reported in Table 1.
Between one cutting test and another, the subject was allowed a two- minute break.

TOOL	CODE AND CHARACTERISTICS
	**E7:** Battery driven electric tool. Batteries are placed in a container (weight approx 2.5 kg) put in a sling (braces plus belt) worn by operator. During pruning stages, the battery is placed at the lumbar zone. Asymmetric beak bladed non progressive scissors (sharp blade and support counter blade). Use of this equipment was judged very light and easy with reduced fatigue at shift end. It was a bit awkward only during olive pruning on ladder.
	**M8:**Manual pruning scissors with ergonomic handles: one of the two arm has a rotating shaped handle to allow better compliance to operating requirements and hand configuration. Subjectively, this typical rotation is appreciated by some workers, while others prefer the same shaped model but fixed. Cutting blades are long and asymmetric beak shaped (sharp blade and support counter blade). They are used for cutting branches with diameter less than =.6-0.8 (small and medium size)
	**M10:**Manual pruning scissors with unshaped traditional handles and short and symmetric cutting blades (double cutting blades).
	**P1:**Pneumatic scissors with double cutting symmetric and very short blades. Pneumatic scissors are all equipped with connection cable of compressed air to a compressor
	**P4:**Asymmetric beak non progressive pneumatic scissors (sharp blade and support counter blade) Pneumatic scissors are equipped with connection cable of compressed air to compressor.
	**P5:**Progressive pneumatic scissors versus pressure degree on button with asymmetric beak blades (sharp blade and support counter blade).Pneumatic scissors are equipped with connection cable of compressed air to compressor.
	**P6:**Progressive pneumatic scissors versus pressure degree on button with asymmetric beak blades (sharp blade and support counter blade). Pneumatic scissors are equipped with connection cable of compressed air to compressor.

Table 1. The tools for pruning used for electromyographic analyses

All the collected electromyographic data were pre-processed via MRXP 1.07 Master editing software (Noraxon, USA) for synchronized view of EMG signal and video and selection of parts regarding the movement to be analyzed and then processed with a dedicated software in Matlab 6.1 environment (TheMatworks, USA) to

assess amplitude parameters (RMS-Root mean Square- 100ms; APDF- Amplitude Probability Distribution Function and Percentiles (10^{th}, 50^{th} , 90^{th}).
All the calculated values saved in a text file were then processed with Excel to extrapolate the diagrams concerning activation levels and spectral parameters.

Results

Rough data

To start presentation of obtained results, in this case as well the following figures will show the rough data obtained in pruning tests of one of the two subjects in the three cases of pruning with manual scissors, pruning with pneumatic scissors and finally pruning with electric scissors (Figures 1-2-3)

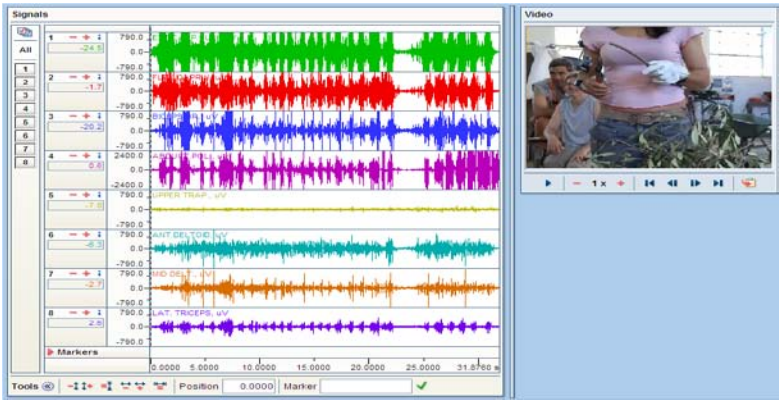


Figure.1 Rough data obtained in pruning test by one of the two subjects using manual scissors

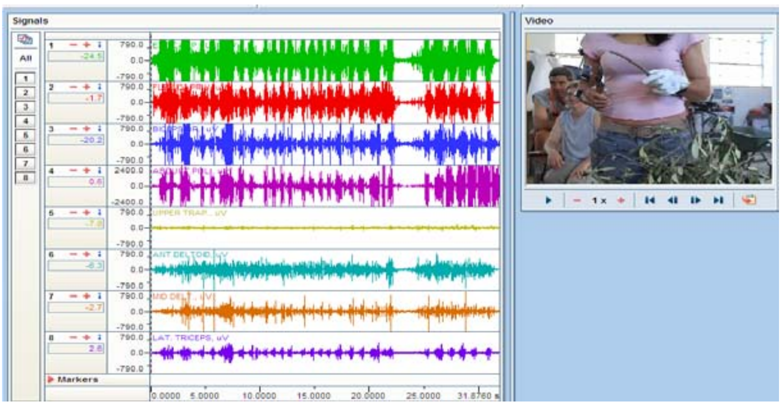


Fig. 2 Rough data obtained in pruning test by one of the subjects using pneumatic scissors

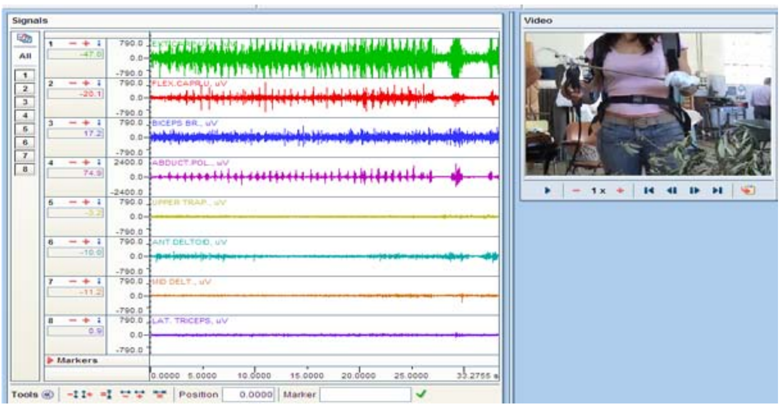


Fig. 3 Rough data obtained in pruning test by one of the subjects using electric scissors

Results of width analysis

In this case electromyography is aimed at identifying the variety of pruning tools to assess which one induces a lower muscular activation level and hence a fatigue lower level over the long period and a lower overload level for affected upper limb joints. The tables and diagrams here below report the percentile values (10°-50°-90°) obtained over the 30 second cutting per subject (TeMo: woman code and GiFo: man code). More specifically the diagrams report:

- *The comparison of the 3 types of scissors (manual, electric and pneumatic) through the values obtained with the two manual scissors and those obtained with the 4 pneumatic scissors by averaging cutting values of small and medium branches.*
- *The values calculated separately for each type of instrument by averaging cutting values of small and medium branches*
- *The values calculated separately for each type of pneumatic and electric tool over cutting values of large branches.*

The activation values (%MVC) corresponding to 10th percentile of APDF (Figures 4-5) obtained by calculating the average values of pneumatic and manual scissors and those obtained with electric scissors by averaging cutting values of small and medium branches remain for male and female below MVC 5%. It is the suggested static load level but for woman's carpus extensor muscles for whom the values are 6.5% MVC for pneumatic scissors, 7 % MVC for manual scissors and 8% MVC for electric scissors.

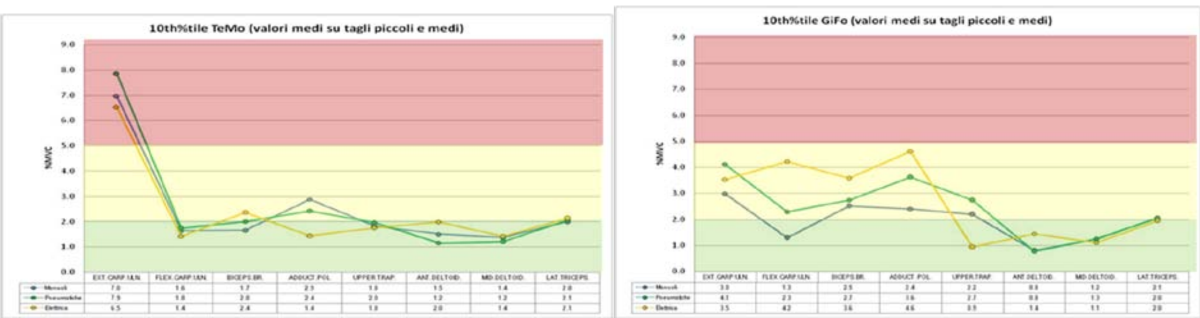
The activation values (%MVC) corresponding to 50th percentile of APDF (Figure 6-7) obtained by calculating the average values of pneumatic and manual scissors and those obtained with electric scissors by averaging the cutting values of small and medium branch remain for female and male below 14% MVC,. It is the suggested static load level limit but for female carpus extensor muscles for whom the values are 15.7%MVC for pneumatic scissors, 18% MVC for manual scissors and 14%MVC for electric scissors and for male inch abductor for whom the values are 18.1%MVC, 11.2%MVC and 16.3%MVC (values in the yellow band for pneumatic scissors and red band for manual and electric scissors). Notice the female's inch abductor who proves to work much more using manual scissors (12.9%MVC, nearly borderline with yellow band) than with the other two types of scissors (5.9%MVC for pneumatic average and 3.3 for electric). This result for male does not seem to be in agreement with female's trend for whom the highest values are still obtained for average of manual scissors (18.1%MVC) followed however by electric scissors (16.3%MVC) and finally by pneumatic average (11.2%MVC).

Activation values (%MVC) corresponding to APDF 90th percentile (Figures 8, 9) obtained by calculating the average values of pneumatic and manual scissors as well as thos obtained with electric scissors by averaging cutting values of small and medium branches remain both for male and female below MVC 70% , which is the suggested static load level limit.

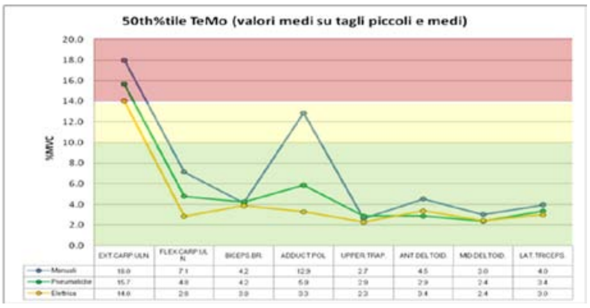
It is worh emphasizing the presence of muscular activation levels exceeding MVC 50 %: updated standars (EN 1005-5 and ISO 11228.3) actually show the presence of risk when there are inner force values equal or higher than MVC 50% for at least 10% of time.

In particular, we found for female 54.4%MVC values in carpus extensor muscles during cutting with manual scissors and values are MVC 54.4% and in male inch abductor during cutting with manual scissors for whom the values are MVC 68.4%. Both for man and female higher peak values are obtained using manual scissors for muscles more involved in movement: carpus extensor, carpus flexor, inch abductor. Lower values on the contrary might be ascribed to electric scissors in some case or to pneumatic average.

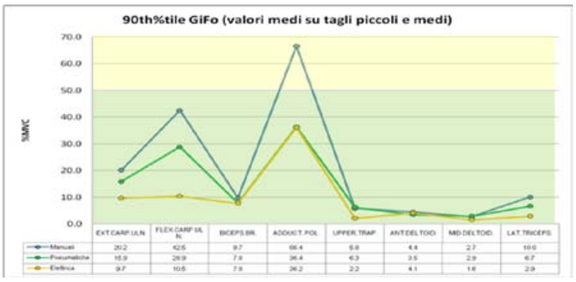
Hence, further processing is needed to distinguish the different types of pneumatic scissors.



Figures 4-5. Diagrams of MVC % 10th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the average values of pneumatic and manual scissors as compared with electric scissors by averaging small and medium cutting values. The diagram highlights the values recommended by Jonson B., 1978 through coloured bands on the background: green = area below limit (<2%MVC), yellow= border area (2-5%MVC), red= area above limit(>5%MVC).

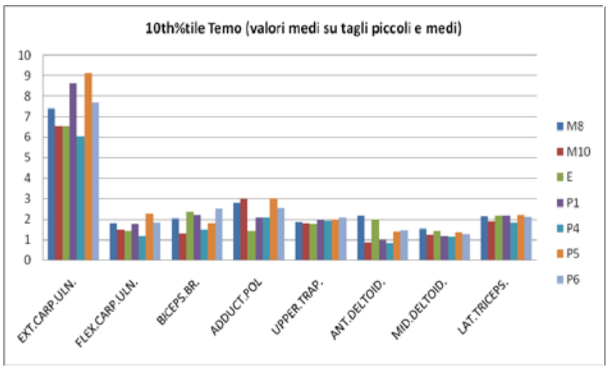


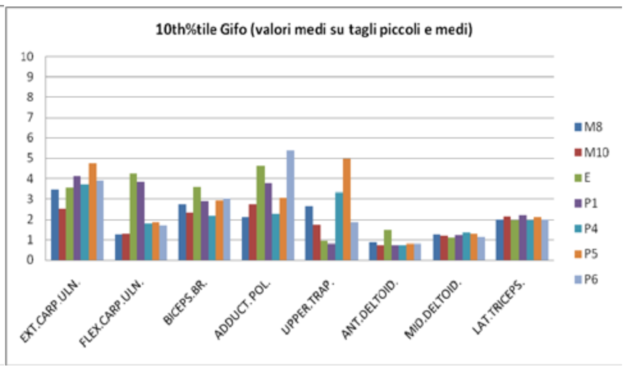
Figures 6-7. Diagrams of MVC% 50th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the average values of pneumatic and manual scissors as compared with electric scissors by averaging small and medium cutting values. The diagram highlights the values recommended by Jonson B., 1978 through coloured bands on the background: green = area below limit (<10MVC%), yellow= border area (10-14 MVC %), red= area above limit(>14MVC%).



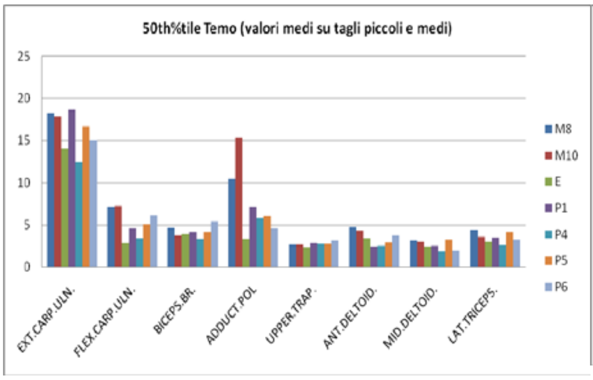
Figures 8-9. Diagrams of MVC% 90th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the average values of pneumatic and manual scissors as compared with electric scissors by averaging small and medium cutting values. The diagram highlights the values recommended by Jonson B., 1978 through coloured bands on the background: green = area below limit (<50MVC%), yellow= border area (50-70 MVC %), red= area above limit(>70 MVC%).

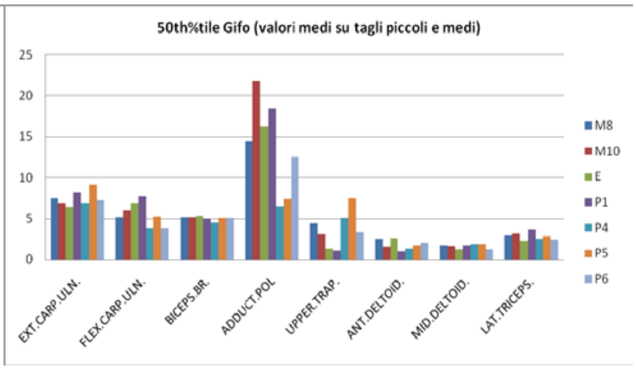
Therefore the diagrams (Figures 10 to 21) report the subsequent values of 10°- 50°- 90° percentile obtained by calculating separately the values of pneumatic, manual and electric scissors and separately also for male and female evidencing when such values fall into green, yellow or red load level bands. They show first of all a different activation level of some muscles: if for the female the most affected muscular group proves to be the forearm extensor, for the male it is the inch abductor.



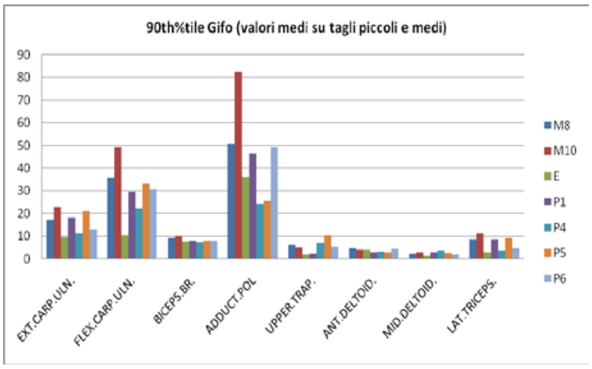


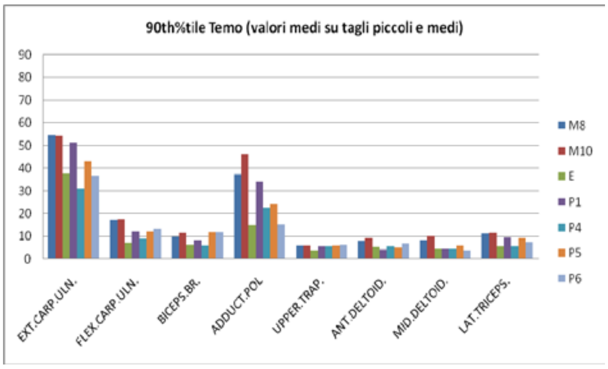
Figures 10 e 11. Diagrams of the MVC % 10th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of tools used by averaging small and medium cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<2%MVC), yellow= border line (2-5MVC%), red= area above limit(>5MVC%).



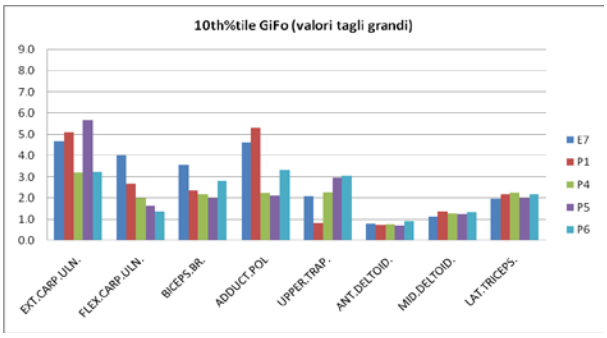


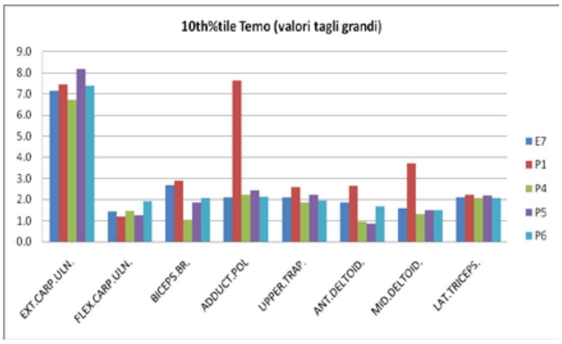
Figures 12 e 13. Diagrams of the MVC % 50th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of tools used by averaging small and medium cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<10 MVC%), yellow= border line (10-14 MVC%), red= area above limit(>14MVC%).



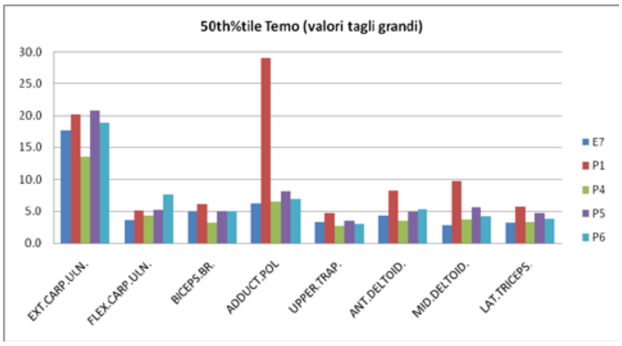


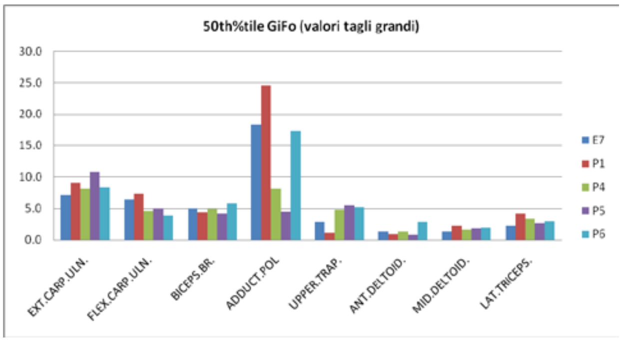
Figures 14 and 15. Diagrams of the MVC % 90th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of tools used by averaging small and medium cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<50 MVC%), yellow= border line (50-70 MVC%), red= area above limit(>70 MVC%).



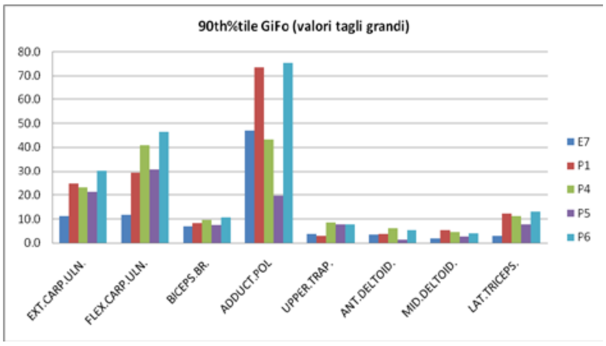


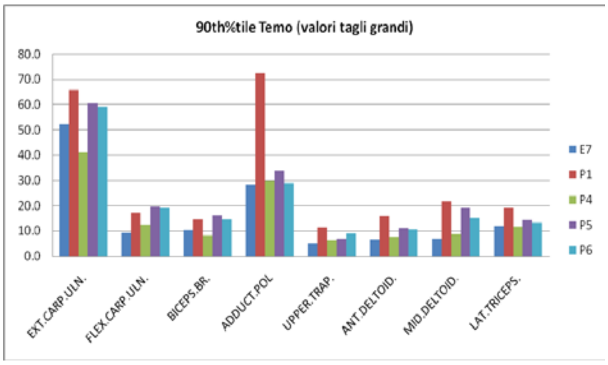
Figures 16 e 17. Diagrams of the MVC % 10th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of pneumatic or electic tool used for large cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<2 MVC%), yellow= border line (2-5 MVC%), red= area above limit(>5 MVC%).





Figures 18 e 19. Diagrams of the MVC % 50th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of pneumatic or electic tool used for large cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<10 MVC%), yellow= border line (10-14 MVC%), red= area above limit(>14 MVC%).





Figures 20 e 21. Diagrams of the MVC % 90th percentile of the two subjects (TeMo: female code and GiFo: male code) obtained by calculating the values separately for each type of pneumatic or electic tool used for large cutting values. In ordinate the coloured arrows evidence the values recommeded by Jonson B., 1978 through coloured bands in the background: green = area below limit(<50 MVC%), yellow= border line (50-70 MVC%), red= area above limit(>70 MVC%).

On the basis of the mere observation of the above diagrams, trends common to the two subjects are anyhow highlighted, in particular as regards manual scissors, observing over threshold values, M8, a manual tool equipped with ergonomic shaping with rotating arm and long asymmetric beak cutting blades leads to average inch abductor activation levels on the subjects of approx 30-33% less than M10, which is a manual tool as well but differing for unshaped traditional handles and short symmetric cutting blades (double cutting blades).

- As regards pneumatic scissors, P4 model (asymmetric beak bladed non progressive scissors) is the only one not showing on average any critical activation level on the two subject and on mall –medium cuttings. P1 (very short symmetric cutting bladed pneumatic scissors), P5 (double cutting progressive scissors versus pressure degree on button with asymmetric beak blades) and P6 (progressive pneumatic scissors versus pressure degree on button with asymmetric beak blades show on the contrary over threshold activation levels as to carpus extensor 10° percentile.
- As regards large cuttings, P4 again appears not to show special criticality whereas P1 and P5 appear to be the most critical for corpus extensor and P1 and P6 for inch abductor.
- Asymmetric beak bladed non progressive electric scissors show values comparable with those of P4 and again fall into gree or yellow band for 10° and 50° and green for 90°.

Discussion of results

Company application results showed that the protocol tested in laboratory can be easily exported also to a working environment and video signal synchronized to electromyographic analysis can be a useful assessment tool also on one individual since the point is just to observe how activation levels change when changing the tool. Hence it is applicable in this case to discriminate muscular levels activation times induced by the use of different tools according to the different actions required and then able to help select the most comfortable tool with the minimum risk of disease for a single individual.

What instead could be derived from assessing average muscular activations in a subject population (heterogeneous as well as by homogeneous subgroups in anthropometric characteristics) could be objectification of a tool ergonomics as compared with another one following anthropometric characteristics.

Diagrams and tables may help the ergonomist understand which muscle is on average more stressed as to the use of different tools and hence make an objective choice protecting the individual or should the study include a significant population sample, it could lead to implementing projects to be applied on large scale. The case studied clearly shows that in pruning the crucial point is a major activity of inch abductor and carpus extensor muscles (these data are confirmed by the high incidence of tendon diseases affecting these body areas).

In short the following considerations arising from this preliminary study are:

- *Long asymmetric beak blades proved to be better than the short double cutting blades for manual and non manual tools*
- *Non progressive non manual tools needing only pressing a key to have full cutting prove to be better in terms of lower activation level needed as compared with progressive tools. Note however that they may produce more injury.*
- *Manual and non manual similar tools showed differences due to a better ergonomic design worth to be investigated by users before adoption.*
  As regards the significant difference observed between male and female regarding the different inch abductor and corpus extensor activation, its meaning is still to be clarified:
- *A preliminary assumption could be the different use of tools by the two subjects and hence the different use of musculature. The different motor strategy observed through a simple video could be quantified for example with a laboratory kinematic study of motor pattern jointly with EMG analysis or more simply by observing a significant population sample.*
- *A second assumption could refer to MVC errors.*

Therefore if the results in absolute terms of percentage load levels should be used with caution, the results regarding activation levels achieved using the different tools would in principle be valid. Actually the obtained results appear to be coherent for male and female.

These preliminary results show that by further improving research programmes on these subjects, two requirement could be met in the short term:

- preparation of educational packages providing buyers with purchasing criteria of a good tool and users with correct instructions for use
- identification of project criteria for technological innovation of pruning tools in collaboration with manufacturers in view of getting an ergonomic trademark by skilled laboratories.

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