Topic 1

“WMSDs Work Related Musculo-Skeletal Disorders”

Oral Presentation

Vegetable grafting in greenhouses: the risk of musculoskeletal disorders for workers due to repetitive movements of upper limbs

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Abstract

The herbaceous grafting in horticulture is a practice widely spread and permits to unite the quality and productivity characteristics with those of resistance to pathology transmitted from the soil, much more quickly as regards the time necessary for genetic improvement.

There are different methods of grafting (crown, cleft, etc.), especially used by skilled workers with the help of manual tools such as the grafting knife. Grafting work requires an effort of upper limbs, owing to the great number of repetitive movements and the precision required to cut the grafting sections.

The above mentioned situation a risk for workers who operate about six hours a day in these conditions.

The risk may involve some pathologies, generally of different origin (such as wrist and shoulder tendinitis, lateral epicondylitis, carpal tunnel etc.), defined as "work related musculo-skeletal disorders" (WMSDs). The Aim of present research is to assess the risk of musculo-skeletal disorders due to repetitive work, for workers employed in manual grafting.

Keywords: OCRA index, work hygiene, WMSDs

Introduction

Steel greenhouses with a thermal polyethylene cover are widespread in horticultural nurseries sited in the Mediterranean basin. In this area, as in others, they are equipped with advanced technologies and computerized plants for irrigation, conditioning and pesticide spreading.

Because of the technology used, capital invested, considerable use of labour, employee management and risks at work, the production process of a nursery can be considered similar to the one used in industry.

Previous research has shown the presence of risks connected with repetitive upper limb movements, the transport of heavy loads and incorrect postures assumed at work (Pressiani and Colombini, 2010).

The exposure of workers to biomechanical overloading depends on the task carried out and varies even for the same task according to the intensity and duration (Colombini et al., 2007). In 2009 a steep rise was recorded for work related musculoskeletal disorders (WMSDs) such as tendonitis, back-ache and tunnel carpal syndrome caused by biomechanical overloading. The figure represented an increase of 36% with respect to 2008 and showed the incidence of these disorders had doubled in five years (INAL report, 2009).

The OCRA method has been used in agriculture for the analysis of the risk involved in various tasks, both in protected environments and in the open field. Relevant research has been carried out in the fields of vine and olive cultivation (Montomoli et al., 2008, 2010), manual pruning in vineyards (Schillaci et al., 2009, 2010; Bonsignore et al., 2010; Camillieri et al., 2010) and some greenhouse operations like pesticide treatments (Balloni et al., 2008), crop care (Schillaci et al., 2009, 2010) and harvesting (Cecchini et al., 2010). There has been a recent study of the risk in flower nurseries, regarding both green houses and the field

(Pressiani and Colombini, 2010). Other interesting research has been carried out in the forestry (Calvo, 2010) and livestock (Camillieri et al., 2010).
The aim of this research is to assess the exposure risk involved in some tasks currently carried out by workers, using the OCRA method (Colombini and Occhipinti, 2005, 2007), in order is to identify the activities characterised by repetitive upper limb movements and give them a specific score.

Material and methods

There are many ergonomic analysis tools that claim to accurately measure some variables associated with WMSDs. They are essentially based on biomechanical, epidemiological, and physiological approaches and identify work activities that might cause WMSDs. These tools include: the OSHA checklist, the strain index, the OCRA index, the ACGIH hand activity level1, the OREGE (Outil de Repérage et d'Evaluation des Gestes), and the RULA (rapid upper limb assessment)10. The OCRA index is the model used by authors. This method is the official European Community (EC) standard (EN 1005-5:2007) for assessing and controlling health and safety risks due to machine-related repetitive handling at high frequencies.
The *OCRA index* was set up by researchers at the Ergonomics of Posture and Movement (EPM) research unit in Milan, Italy. The model is based on three requirements: 1) to thoroughly evaluate the contribution of different multiple risk factors estimate; 2) to develop an index to estimate the type of risk for various jobs, so that it is possible to compare different indexes and measure the changes should the work shift be re-planned; 3) to determine the repetitive movements of the upper limbs and the maximum frequency of actions per minute recommended in good conditions.
In the "grafting" sector grafted vegetables are produced. Grafting is carried out manually on table (figure 1). The operators are seated.

Figure 1.Orview of the greenhouse where vegetable grafting is carried out

In order to determine the number of actions carried out, the work shift was studied by analysing the operations carried out, including the work breaks and their durations (table 1).

Table 1. Study of work shift

Job	Description	Duration (min)	Type of Job (repetitive/not repetitive)
Grafting	Manual grafting with knife	225	Repetitive Recovery Time or Not
First break	Lunch break	105	Recovery time
Second break	Breaks due to cleaning, supply	30	Recovery time
Total minutes of actual work and breaks		360	

Results

In order to apply this model to the vegetable graft phases, we began by calculating the number of actions carried out during the cycle. To graft a vegetable, 15 actions with the right limb and 6 with the left limb are performed in 20 seconds. The workers make movements that involve the same portions of the limb for almost all the time (*ReM* = 0.7 for the two limbs). With the right upper limb the worker takes the plant (1), places it on the table (2), removes the right basal leaf (3), removes the left basal leaf (4), puts removed leaves in the container (5), takes the knife(6), cut the plant at the base on the right side (7), cut the plant at the base on the left side (8), rests the knife on the table (9), takes the rootstock (10), insert the plant into the rootstock (11), takes the clip (12), inserts the clip at the base junction between the rootstock and the plant (13), insert the grafted plant into the container (14), moves the arm to the new plant (15). The worker stretches out the left arm towards the plant (1), takes hold of it (2) and picks it up (3), pulls back the arm (4), bends the wrist downwards (5), and lastly cuts the plant into two different parts (6).

Figure 2. Overview of the work cycle

The number of actions carried out in the time unit (*FF*) (eq. 1-2) is therefore:

$$FF_r = 60 \times \frac{15}{20} = 45 \text{ actions/min (right limb)} \quad (1)$$

$$FF_l = 60 \times \frac{6}{20} = 18 \text{ actions/min (left limb)} \quad (2)$$

which results in a total number of actions per shift (*ATA*) (eq. 3-4) equal to:

$$ATA_r = 45 \text{ actions/min} \times 225 \text{ min/shift} = 10125 \text{ actions/shift (right limb)} \quad (3)$$

$$ATA_l = 18 \text{ actions/min} \times 225 \text{ min/shift} = 4050 \text{ actions/shift (left limb)} \quad (4)$$

In the calculation of *ATA*, 225 minutes (D) were used because, during a 6-hour shift, there are some minutes when the workers do not make repetitive movements (e.g. when they take a rest or put the little plants in the appropriate stations).
Once the number of total actions per shift was established, the multiplicative factors were applied to calculate the recommended number of actions (*RTA*) per shift. A score of 0.5 on Borg’s scale was assigned to the force factor for each technical action of the left upper limb (meaning an extremely light amount of force), corresponding to a multiplicative coefficient (F_{oM}) equal to 1. A score of 1 on Borg scale was assigned for each technical action of the right upper limb (meaning a very light amount of force), corresponding to a multiplicative coefficient (F_{oM}) equal to 0.85.
For the posture factor, a minimum multiplicative factor (P_{oM}) of 0.33 was used for both limbs. Regarding the complementary factors (for example the use of gloves), a factor (*AdM*) of 0.90 was used for the right limb (complementary factors present for 2/3 of the cycle time) and 0.95 for the left limb (complementary factors present for 1/3 of the cycle time).
The relationship between working time and recovery periods was between 7/1 and 11/1 during the first two working hours, from which we get a multiplicative factor (Rc_M) equal to 0.8, since in this case the recovery periods were considered not satisfactory. The duration multiplier (D_{uM}) is equal to 1.5 (total time devoted to repetitive tasks during shift was between 181 and 240 minutes).
The recommended number of actions for the right limb (RTA_r) (eq. 5) was then calculated:

$$RTA_r = 30 \times 0.85 \times 0.33 \times 0.90 \times 0.7 \times (225 \times 0.80 \times 1.5) = 1431 \text{ actions/shift.} \quad (5)$$

From the relationship between *ATA* and *RTA* (eq. 5), we get the exposure index for right limb:

$$OCRAindex_r = 10125 / 1431 = 7.1 \quad (6)$$

The recommended number of actions for the left limb (RTA_l) (eq. 7) was then calculated:

$$RTA_l = 30 \times 1 \times 0.33 \times 0.95 \times 0.7 \times (225 \times 0.8 \times 1.5) = 1778 \text{ actions/shift.} \quad (7)$$

From the relationship between *ATA* and *RTA* (eq. 1), we get the exposure index for left limb:

$$OCRAindex_l = 4050/1778 = 2.3 \tag{8}$$

The index values up to 2.2 are acceptable; values between 2.3 and 3.5 represent a possibility of risk, and values higher than 3.5 are considered unacceptable, and therefore the way in which the job is carried out should be modified. The value of *OCRA index* for the right limb is 7.1; so it is situated in unacceptable zone (red zone – high risk).
For the left limb the *OCRA index* is 2.3 (very low risk), situated in the yellow zone, that means possibility of risk.

Conclusions

In the case of vegetable grafting in the greenhouse, the greatest disadvantage seems to be the frequency of movement. Two other important risk factors are the posture and the repetition. Grafting operations force workers to maintain an elbow pronation greater than 60°, with respect to a resting position, for 80% of the cycle time. Repetition is particularly risky due to very short cycles that are repeated for more than 50% of the working time. It does not seem possible to eliminate the risk of biomechanical overload in this job, but at least it could be reduced. Increasing the number of workers would not make a great difference either: this would lead to a high exposure to risks of WMSDs .
More workers would not solve the problem because the *OCRA index* is too high, and reducing it to an acceptable level would require too many people.
The results of this research show a high risk for the right limb which effects the cutting up on the small vegetables to be grafted and a low risk for the left limb. The factors which have contributed to reach such results are to be attributed to the continuous pinch of the knife, to the great number of movements and to the lack of recovering time.
Despite these limitations, the findings from our study demonstrate that alternative patterns of rest breaks, including brief rest breaks early in the work shift, may reduce workers' musculoskeletal discomfort and fatigue over the course of the day with modest impact on production. Therefore, it would be a good idea to reorganize such work by including recovery times right from the earliest working hours. Although we tested the rest break intervention in agriculture, similar solutions are likely to benefit workers in other strenuous jobs such as construction and manufacturing.

References

ACGIH. 2001. Threshold limit value for chemical substances and physical agents and biological exposure indices. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists.

Apostoli, P., Bazzini, G., Sala, E., Imbriani, M. 2002. La versione italiana "OREGE" (Outil de Repérage et d'Evaluation des Gestes) dell'INRS (Institut National de Recherche et de Sécurité) per la valutazione dei disturbi muscolo-scheletrici dell'arto superiore. G. Ital. Med. Lav. Erg. 24: 3-25.

Borg, G. A. V. 1982. Psychophysical bases of perceived exertion. Med. Sci. Sports Exercise 14(5): 377-381.

Cecchini, M., Colantoni, A., Massantini, R., Monarca, D. 2010. The risk of musculoskeletal disorders for workers due to repetitive movements during tomato harvesting. J Agric Saf Health. 16(2): 87-98.

CEN. 2007. EN 1005-5 Safety of machinery - Human physical performance - Part 5: Risk assessment for repetitive handling at high frequency. Brussels, Belgium: European Committee for Standardization.

Colombini, D., Occhipinti, E. 1997. Application of concise exposure index (OCRA) to tasks involving repetitive movements of the upper limbs in various industrial settings: Preliminary experience and validation. Occup. Health and Ind. Med. 37(2): 76-79.

Colombini, D., Occhipinti, E. 2006. Preventing upper limb work-related musculoskeletal disorders (UL-WMSDS): New approaches in job (re)design and current trends in standardization. Appl. Ergon. 37(4): 441-450.

Grieco, A. 1998. Application of the concise exposure index (OCRA) to tasks involving repetitive movements of the upper limbs in a variety of manufacturing industries: Preliminary validations. Ergonomics 41(9): 1347-1356.

INRS. 2000. Method de prevention des troubles musculosquelettiques du membre superiore et outils simplex. Doc. Med. Trav. 83(3): 187-223.

Mc Atamney, L., Corlett, E. N. 1993. RULA: A survey method for the investigation of work-related upper limb disorders. Appl. Ergon. 24(2): 91-99.

Merseburger, A. 1996. Movimenti ripetitivi degli arti superiori: risultati della valutazione dell'esposizione e dell'indagine clinica nella selezione e confezionamento delle mele. La Medicina del Lavoro 87(6): 603-612.

Monarca, D., Cecchini, M., Panaro, V. 2001. Analisi dei rischi di affezioni muscolo scheletriche da lavoro ripetitivo per gli addetti ad alcune operazioni agricole e agroindustriali. In Proc. AIIA 2001 Ingegneria Agraria per lo Sviluppo dei Paesi

Moore, J. S., Garg, A. 1995. The strain index: A proposed method to analyze jobs for risk of distal upper extremity disorders. American Ind. Hyg. Assoc. J. 56(5): 443-458.

Occhipinti, E. 1998. OCRA, a concise index for the assessment of exposure to repetitive movements of the upper limbs. Ergonomics 41(9): 1290-1311.

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Exposure to risk of injury and ergonomic load during beef cattle handling in open areas

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Abstract

Working with beef cattle in open areas has been shown to expose workers to a high risk of musculoskeletal injuries and/or over exertion. The aim of this presentation are to identify and review the data on injuries to workers when working with beef cattle in open areas, and summarize critical livestock handling practices that would enhance worker safety. The study was based on work carried out as field studies on seven Swedish beef farms, where the risk factors in connection with farmers' work with cattle on pasture were investigated. Duration and sequence for the identified tasks were observed and registered during the farmer's driving, sorting, transporting and relocating cattle. The risk of injuries were assessed for the tasks observed using Working Environment Screening Tool in Agriculture (WEST-Ag). This tool is a modified version of the WEST, which was designed to assess the work environment. The results from the findings of this work will be used in the development of educational resources that target small beef producers. It is anticipated that adoption of the recommended practices will reduce the risk of injury. Cattle handling activities in open areas present a significant level of risk of injury and over exertion to the farmers. Practices implemented to reduce the farmer's exposure to the aggressive behaviour of the cattle and other related hazards have been effective on some beef farms. Inexpensive animal handling technology could be incorporated to enhance the safety of the farmer and the welfare of the cattle.

Keywords: animal handling, livestock safety, working environment

Introduction

Working with beef cattle in open areas, such as pasture and open feedlots, exposes workers to a high risk for traumatic and musculoskeletal injuries or over exertion. The most serious hazards are associated with the direct exposure between the worker and the animal. In Sweden, five fatalities were documented during cattle handling activities in open areas during 2010 and 2011 (LRF, 2010; LRF, 2011). Sheldon et. al. (2009) reported on 287 bull-related attack of which over half (57%) were fatal and nearly 14 % took place in a pasture setting. Field (2011) noted that small and part-time beef farmers account for a disproportionate percentage of both fatal and serious farm-related injuries.

Cattle that are not restrained or contained in pens or feedlots, as with beef rose on pasture, are unpredictable in their behaviour and have the capacity to act in aggressive ways if approached or sense that their territory or their young are being threatened. These defensive behaviours can lead to a worker being butted, gored, kicked or mauled due to the superior strength, size and quickness of the animal (AFS, 2008:17; Hendricks and Aderoya, 2001; Geng and Salomon, 2010; Geng and Salomon, 2011). The severities of injuries that can be caused by cattle have been reported by others (Reiling1997; Drudi, 2000; Sheldon et. al., 2009; Health and Safety Authority, 2011). Field (2011) also identified other beef handling-related hazards, including: use of tractors without protective cab or ROPS to herd beef cattle on pastures; falls associated with rough terrain, slippery surfaces and while climbing across fences; needle sticks occurring during animal treatment; the use of all-terrain vehicles; and vehicle collisions with cattle that enter public roadways.

In addition to traumatic injuries, beef producers are also at risk from other cattle handling operations. It has been well documented that livestock handling, in general, involves high physical demands that increase the risk of musculoskeletal injuries or exertion (Vingård et al., 1992; Stiernström et al., 1998; Holmberg et al., 2005; Hartmann et al., 2005; Sheldon et. al., 2009; Geng and Salomon, 2010; Geng and Salomon, 2011).

The aims of this presentation are to identify and review the currently available data on injuries to workers when working with beef cattle in open areas, and to summarize critical livestock handling practices that have a high potential for enhancing worker safety.

Materials and methods

Findings are include data gathered during a pilot field assessment of work environment carried out on seven Swedish farms during the pasture season, where the risk factors in connection with farmers' work with cattle in open areas were observed and documented.

The sample farms and participants as well as the tasks observed are described in table 1. Four of the farms had cattle on pasture all year, and the other three only pastured during summer season (between May-September). The size of the herds varied from 53 to 225 cattle (numbers of bull per farm are from 1 to 5). The areas of pasture per farm are from 30 to 130 hectares. The farmers performing the tasks and working conditions were observed during driving, transporting and relocating cattle in the pastures. At each farm, most of the tasks observed were carried out by at least 2 persons. Six of the farms utilized temporary collecting pens with foddering built on the pasture (1-15 days) before the day of cattle handling.

Also, a detailed interview was carried out with the seven male farm owners. The ages of the participators were between 29 to 63 years. Their working experiences with animals were from 11 to 45 years. Traumatic injuries during cattle handling were reported at four of the farms.

Table 1. Information about the farms, participants and their tasks studied

Farm code	No. of cattle/(bull)	Pasture area (ha)	Pasturing period	Farmer age (year)	Farmer experience (year)	Tasks studied	Worker (no.)
Farm 1	71 (1)	35	Whole year	48	30	moving, sorting, separating out 11 suckle cows	2
Farm 2	53 (1)	35	Whole year	57	11	moving, sorting, separating out 13 young bulls & 3 heifers	4
Farm 3	63 (1)	30	Whole year	56	40	moving, sorting, separating out 13 young bulls & 15 heifers	2
Farm 4	61 (3)	33	Whole year	63	30	transporting 18 cows & 18 calves to barn from two pasturelands	2
Farm 5	124 (4)	70	May-Sept.	29	18	transporting 19 cows & 19 calves to another pastureland	2
Farm 6	225 (5)	180	May-Sept.	40	25	moving, sorting, transporting 27 cows & 24 calves to barn	3
Farm7	204 (4)	130	May-Sept.	47	30	moving, transporting 17 cattle to barn	2

*Years of working experiences with animals

The risks of injuries at each site were assessed for the current tasks using the Working Environment Screening Tool in Agriculture (WEST-AG, Torén et al., 2004). The WEST-AG is a modified version of a WEST method (Karling and Brohammer, 2002). The method transposes the exposure in the working environment into an effect on human health in economic terms in Swedish Krona per thousand working hours (SEK/th).
With the WEST-AG, seven factors can be screened, i. e., risk for injury, ergonomic load, psychosocial factors, noise, vibrations, chemically health hazards and work environment in general. For each factor, there is a model for the exposure to the factor and a method to translate this exposure into health effects. Each work situation gives positive or negative contributions to the factor of interest. Thereby, a representation of the working environment is obtained, showing which factors should give negative or positive contributions. The exposure from the factor into health effects are expressed as the effect on productivity for the farm screened. In this study, the working environment was screened for two factors, i. e., risk for injury and ergonomic load.
The screening for risk of injury was performed by risk assessment of 15 components on an 11-degree linear scale and recalculation of the ratings through the model into the WEST-points. The 11-degree linear scale ranged from zero (no/trivial risk) to 10 (extremely high risk), and the 15 components were 1) injury by machine in motion, 2) to be struck by flying object, 3) to be struck by falling object, 4) overexertion of body part, 5) handling injury by hand-tools or other working materials, 6) impact due to disorder, cramped or blocked room, 7) injury with vehicle, 8) fall on the same level, 9) fall to lower level, 10) misstep, 11) contact with chemical, 12) burn or frostbite, 13) electrical injury, 14) explosion or fire, and 15) injury

by person or animal. Table 2 shows an example of risk assessment with the risk scale for one of the 15-component "injury by person or animal" (Geng, et al., 2009).

Table 2. Example of risk assessment of component No. 15: injury by person or animal.

Contact with violent person or dangerous animal	**Description of the risk**	**Risk scale**	**Result**	**WEST-AG-point SEK/1000h**
Unintentional injury by person due to wrongly designed workstation. Injury by animal (e.g. cow/bull with horns, loose bull, etc.). Physical or psychological injury by person through violence, threat, aggression, etc.	Extremely high risk	10		-3555
	Intolerable risk	9		-3025
	High risk	8		-2533
	Substantial risk	7		-2079
	Increased risk	6		-1664
	Moderate risk	5		-1287
<u>*Comments:*</u>	Relatively low risk	4		-949
	Low (tolerable) risk[a]	3		-650
	Very low risk	2		-389
	Minimal (trivial) risk	1		-166
	Non-risk	0		0

[a] Acceptable risk level

The screening of ergonomic load is based on judgment of four bases i. e., 1) working posture, 2) repetitive work, 3) weigh/force to be handled and 4) modifying factors. The modifying factors consist of the information about worker's age, gender, precision task, the task include snatch, local pressure against anatomic structures and work in hot/cold environment. The WEST result of ergonomic load (WEST-erg, SEK/th) is then calculated by:

$$WEST_{-erg} = (wp + rw) * weight(force) * mf \qquad (1)$$

where **wp** *is working posture,* **rw** *is repetitive work and* **mf** *is modifying factor.*

Results

Figure 1 shows the results from screening the risk of injury during working with cattle in the pasture at seven farms. The risk mainly involves potential injury by animal, overexertion of body part and falls on the same level.

Clearly, the risk of injury caused by animal contact was higher during handling of cattle at three farms (Farm 1, Farm 2 and Farm3) as compared to the other farms. The farmers working on farm 3 also had a higher risk for overexertion of body part. The reason to the high minus score was that the farmers had to lift, carry and move the heavy steel-gates (>40 kg) to build temporary gathering areas.

The result of WEST-point of -2500 SEK/1000hour indicates that the farmers are exposed for risk of injury in the working environment, which corresponds a cost on 2 500 SEK per thousand working hours (or 2.5 SEK/hour) during handling cattle in open pasture.

In addition, the answers on the question about the most stressful activities experienced by the famers were: care and label tagging newborn calves during calving, separating calf from cow, looking for animals escaped from their handling area to another animal group, driving cattle to temporary pens and loading cattle into transporting trailers before slaughtering, etc.

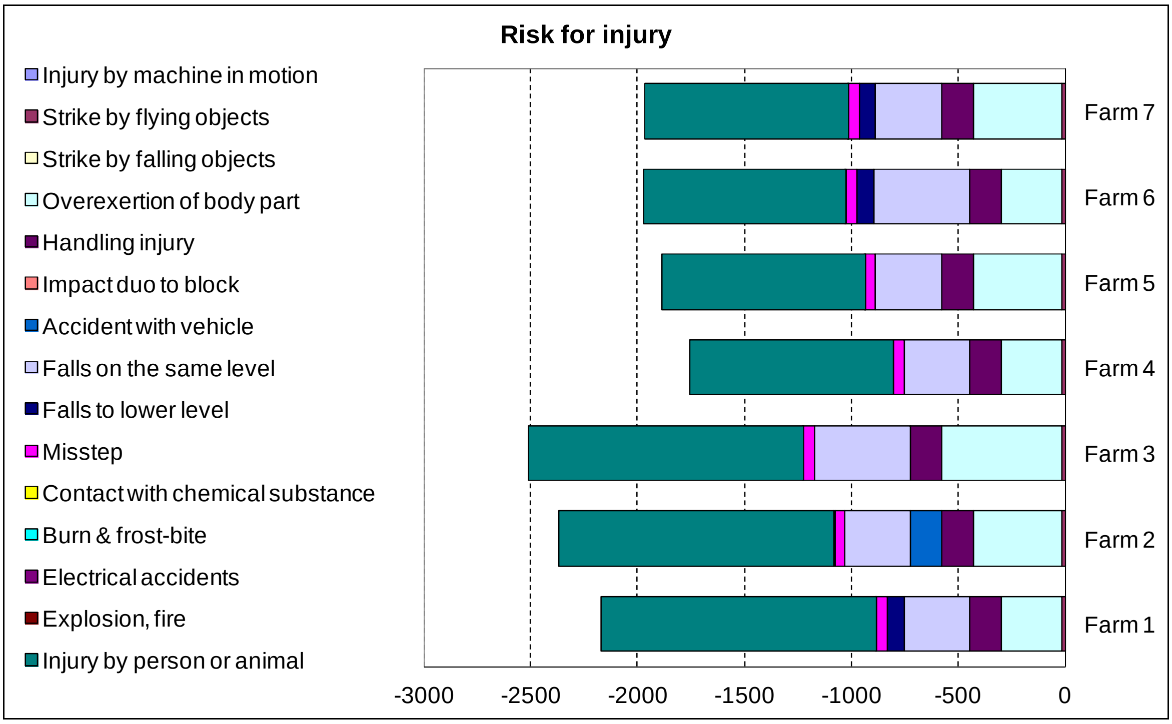

Figure 1. Risk of injury for the seven farmers when working with cattle on the pastures.

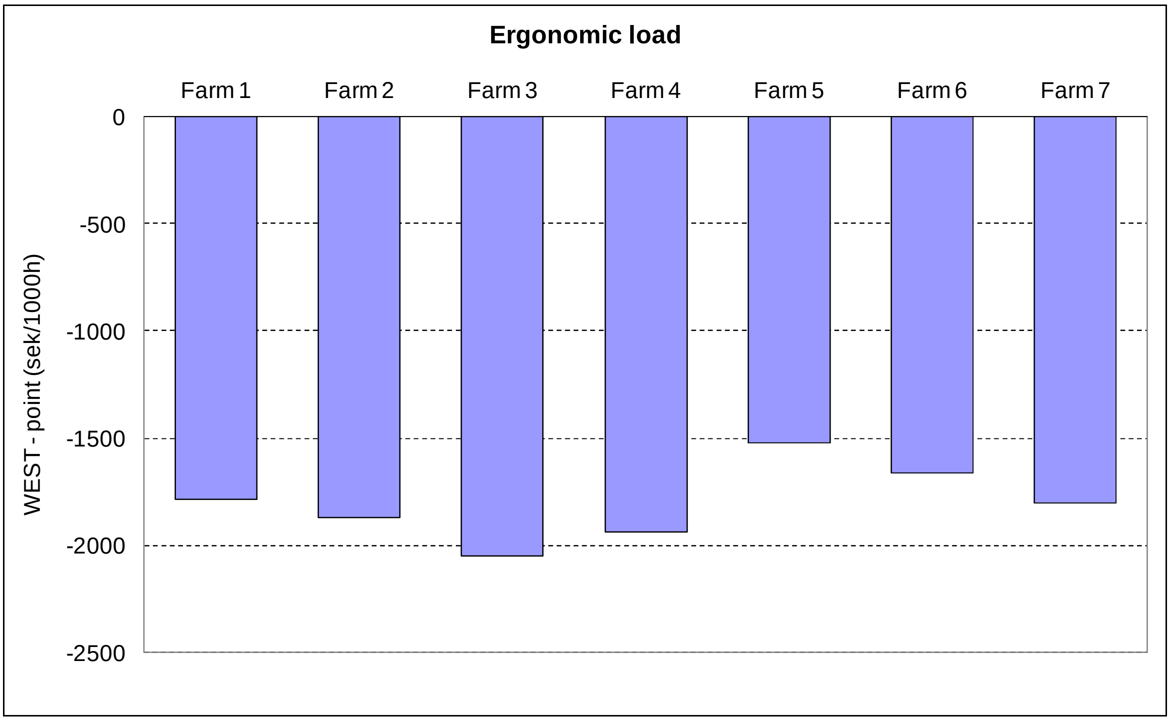

Figure 2 WEST-points on ergonomic load on the farmers during working on the cattle handling on the pastures.

Some differences of WEST-point on ergonomic load (-1525 to -2052 SEK/1000h) among the seven farms were assessed. This is because a different weighing factor of *weight/force* was handled within the farmers' work at their farms. Also, a different age of worker resulted in a different weighing effect of modifying factor. According to the method, a weighing factor

issues from the modifying factors of age is 40 years = 1.2, 60 years = 1.4. For instance, the farmer at the farm 3 was 56 years (Table 1) and he carried and moved the heavy gates. These higher weight/force and aged elements used to calculate in the WEST-erg (equation 1) caused the higher minus points on ergonomic load than for other farmers.
Results from the detailed interview with farmer indicated that caring the steel-gates and pushing cattle into the transport vehicles were the most heavy tasks.

Discussion and conclusions

The results demonstrated that the cattle handling activities in open areas can cause a greater level of risk of injury and over exertion to the farmer, especially, gathering and sorting. Therefore good knowledge of the animals' behaviour is important for animal handling, such as Low Stress Stock handling (LSS-method, Smith, 1998), which would enhance the safety of the farmer and the welfare of the cattle.
Also, it was noticed that all of the farmers interviewed had considerable experience with cattle handling and had developed different practical approaches to reduce the farmer's exposure to the aggressive behaviour of the cattle and other related hazards, including:

- Setting up temporary collecting pens with feed in pasture areal at least one week before gathering to attract cattle into the pen and let the animals become used to the pen.
- Using a tractor or All-Terrain Vehicles with feed to tempt and lead animals into the gathering pen.
- Loading calves into the wagon first before cows for transporting, as mother animals want to follow their young into the trailer.
- Handling and transporting bulls together with some female cattle to reduce the farmer's exposure to the aggressive behaviour of the bull.
- Equipment being incorporated for carrying and moving of heavy steel-gates in order to reduce ergonomic load on the farmers and risk for musculoskeletal injuries as well.

Recommendations

Based upon the review of current injury data related to beef cattle handling and the findings of risk assessment by the WEST-AG, the following intervention strategies should be promoted to Swedish beef producers:

1. The level and frequency of direct exposure between the worker and cattle should be kept to a minimum. This includes efforts to construct and maintain suitable fencing, gates, temporary holding pens and loading chutes. The literature and farmer interviews suggested that further work is needed to clarify the engineering aspects of cattle handling facilities to ensure that their capacities are sufficient relative to animal size, weight and strength.
2. When direct contact with cattle is required, such as for medical care, castrating, branding, dehorning and identification tagging, the use of appropriate head gate and squeeze chutes should be recommended practice. Workers should be trained in the proper use of these devices.
3. The use of appropriate all-terrain vehicles by trained workers should be considered as a means of reducing physical contact with cattle in an open setting and to navigate rough terrain to complete fence maintenance, check on herd and pasture condition, and looking for missing cattle. Working alone, on-foot in an open pasture with no ready way for escape is a well recognized hazard that should be avoided. These vehicles however, present a new set of personal hazards that need to be considered.

4. The ergonomic characteristics of current cattle handling facilities and equipment need to be assessed in light of new findings concerning causes of musculoskeletal injuries and advances in technology. Fencing, gate use, and cattle handling equipment required high levels of physical exertion due to the weight of the equipment designed to match animal weight and strength. New technology such as light weight gates, automatic gate openers, high tensile fencing, portable head gates and loading chutes, tractor mounted feeding equipment can play a significant role in reducing the risk for musculoskeletal injury.
5. Beef producers should be encouraged to weed out more aggressive cattle and to breed for higher level of desirable handling qualities. Bulls that become overly aggressive towards workers and cows that are overly protective of their new calves are a high risk of carrying worker injury or damage to facilities. These animals should be sold for slaughter purposes only and not sold or transferred to another farm where they continue to be a threat.
6. Older beef producers who may experience diminishing physical abilities need to be encouraged to use extra caution when exposed to cattle in open spaces. Reduced mobility impaired vision and hearing can increase the risk of a surprised encounter with an animal or make escape more difficult.
7. Opportunities should be provided to all small beef producers to receive training on strategies related to reduced stress livestock handling. This includes discouraging worker behaviours that increase flightiness and facilities that generate unnecessary livestock anxiety.

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References

AFS. 2008:17. Arbetsmiljöverkets föreskrifter om arbete med djur. Stockholm. http://www.av.se/lagochratt/afs/afs2008_17.aspx '. (In Swedish).

Drudi, D. 2000. Are Animals Occupational Hazards. Bureau of Labor Statistics. Compensation and Working Conditions. Fall 2000, 15-22.

Field W. E. 2011. Beef Operation, Safety, and Health. In: Cow-Calf Production in the U.S. Corn Belt. MWPS-66, Mid West plan Service / Iowa State University / Ames. Iowa. USA. 205-214.

Geng Q., Torén, A., Salomon E. 2009. Screening the Working Environment in Outdoor Pig Systems. Journal of Agricultural Safety and Health. 15(3): 283-297.

Geng Q., Salomon E. 2010. Working environment in a mobile system for beef production during the winter. International Conference on Agricultural Engineering, AgEng 2010. Clermont-Ferrand, France. September 6-8, 2010. Paper nr: REF 139, Book of Abstracts, 144.

Geng Q., Salomon E. 2011. Identifiering av risk för arbetsskada i utomhussystem för nötköttsproduktion under vintern. Slutrapport H092-0003-SLO. JTI – Institutet för jordbruks- och miljöteknik. (In Swedish).

Hartmann E., Oude Vrielink H., Metz J. et al. 2005. Exposure to physical risk factors in Dutch agriculture: effect on sick leave due to musculoskeletal disorders. International Journal of Industrial Ergonomics. 35, 1031-1045.

Health and Safety Authority. 2011. Guidance on the Safe Handling of Cattle on Farms. Health and Safety Authority, the Metropolitan Building, James Joyce Street, Dublin.

Hendricks K. J., Adekoya, N. 2001. Non-fatal animal related injuries to youth occurring on farms in the United States, 1998. Injury Prevention. 7(4): 307-311.

Holmberg S., Thelin A., Stiernström E.L., Svärdsudd K. 2005. Low back pain comorbidity among male farmers and rural referents: a population-based study. Ann. Agric. Environ. Med. 12: 261–268.

Karling M., Brohammer G. 2002. WEST – en metod som bedömer hela arbetsmiljön. IVF-skrift 02801. IVF – Industriforskning och utveckling AB, Mölndal, Sverige. (In Swedish).

LRF. 2010. Dödsolyckor 2010. Lantbruks- och skogsbrukarbete samt barnolyckor. Sammanställning av Lantbrukarnas Riksförbund. (In Swedish).

LRF. 2011. Dödsolyckor 2011. Lantbruks- och skogsbrukarbete samt barnolyckor. Sammanställning av Lantbrukarnas Riksförbund. (In Swedish).

Reiling J. R. 1997. Agricultural Injuries in Norway. Journal of Agromedicine, 4:3-4, 285-294.

Sheldon K., Deboy G. R., Field W. E, Albright J. 2009. Bull-related Incidents: Their Prevalence and Nature. Journal of Agromedicine. 14:357-369.

Stiernström E-L., Holmberg S., Thelin, A., Svärdsudd K. 1998. Reported health status among farmers and nonfarmers in nine rural districts. Journal of Occupational and Environmental Medicine. 40 (10), 917-924.

Torén A., Geng Q., Andersdotter M. 2004. WEST-agriculture - a method for screening of the working environment in agriculture. Presented at Nordic Meeting on Agricultural Occupational Health (NMAOH), Hamra, Sweden, 29 Nov - 1 Dec 2004.

Vingård E., Alfredsson L., Fellenius E., Hogstedt C.1992. Disability pensions due to musculoskeletal disorders among men in heavy occupations: a case-control study. Scandinavian Journal of Social Medicine. 20 (1), 31-36.

Work-related musculo-skeletal disorders in farm workers of eastern Sicily

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Keywords: repetitive movements of the upper limbs; manual handling of loads; agriculture

Objectives
Sicily is home to 14% of Italian commercial farms. Their workforce is predominantly comprised of the farmers and their families (>75%). All such tasks involve a degree of exposure to safety and health risks. Over the last 5 years, 5% of all occupational accidents in Italy have occurred in Sicily; 13% were fatal. Occupational diseases, which affect <2% of farm labourers, are predominantly noise-induced hearing impairment and respiratory conditions (nearly 80%); osteoarticular conditions affect <10% of farm labourers.

Methods
The study involved 370 labourers from 13 commercial farms in eastern Sicily. Each participant underwent a number of clinical and instrumental tests and examinations and was asked to fill in a questionnaire inquiring about job type, tasks and their mode of execution, and osteoarticular conditions, especially those affecting the spine and the upper limb girdles. The OCRA and NIOSH index were applied to assess the risk of exposure to repetitive movements of the upper limbs (RMUL) and the risk related to manual handling of loads (MHL).

Results
The mean age of the subjects involved in the study was 43.4 years (±7.6) and their mean job seniority was 21.6 years (±6.3). Seven farms produced vegetables and six produced fruit and citrus fruit.
The RMUL and MHL exposure assessment demonstrated a high degree of risk exposure for all labourers in relation to the tasks involved by the tending of different products. The risk was especially high to develop low-back pain and other musculoskeletal conditions.
The present findings suggest the need for training farm workers and for adapting and renovating the work equipment to reduce the number of occupational injuries; in particular all those surveyed were found to be exposed to MHL, biomechanical overload and incongruous postures. The fact that most tasks are performed in environments, like fields and conservatories, where the microclimate cannot be controlled compounds the problem.

Analysis of stress produced during manual pruning in Vineyard: the study of anthropometric parameters

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Abstract

Winter pruning of the vines, though conducted with pre-mechanized operations, requires care in determining the type of farming and for the respect of the gems needed for the proper performance of fructification and the potential of the crop, manual intervention with shears and based on rapid and precise movements. For this reason many studies are developed to evaluate possible influences on musculoskeletal upper limb. In recent years there has been a line of research aimed at developing tools that can provide measurements of the effort, with the aim of replacing subjective evaluations from a panel of professionals interviewed during the action. The provision of a kit consisting of a shear equipped with sensors made it possible to map the efforts made by hand in order to evaluate both the overall effort to that produced by single muscle compartments. Experimental tests were conducted in the laboratory on branches from vineyards during winter pruning on a group of 10 healthy volunteers subjected to tests using cutting shears types on the market, mainly different for characteristics of the handle and blade. Were recorded for each individual: age, weight, height, length, width and thickness of the hand volume, length, width, volume and thickness of the arm and forearm. During the cutting operation has been detected effort of the hand in terms of intensity and duration by a shear equipped with sensors. The aim of this paper is to establish a relationship between anthropometric parameters and stress as a function of the hand grip of the different types of cutting tool.

Keywords: security, shears, upper limb

Introduction

All pre-mechanized operations in vines pruning require a precision handiwork to determine the type of farming and to respect gems for the performance of fructification and the potential of the crop.

These operations need accurate and rapid movements of hand and arm so for this reason are the subject of studies to evaluate possible influences on musculoskeletal upper limb impairment. In fact pruning with hand-powered pruning shears increases the risk of musculoskeletal hand-wrist disorders (Roquelaure et al., 2001) mainly because of the magnitude of the physical load during the pruning task which requires repetitive handgrips and wrist movements (Roquelaure et al., 2002), combined with static work in the upper arm-shoulder system (Wakula et al., 2000). Higher grip and push forces further yield increased electrical activity of the m.flexor carpi ulnaris and finger-flexor muscles, and reduced peripheral circulation of fingers (Hartung et al., 1993; Gurram et al., 1995; Miyashita et al., 1990). Reidel (1995) investigated the influence of grip and push forces on the acute reaction of the hand-arm system under vibration exposure in terms of biodynamic response, shifts in vibration perception threshold and subjective vibration sensation.

Many studies have suggested that the magnitude of the hand force imparted on a vibrating tool handle affects the severity of exposure to the hand–transmitted vibration and hand–wrist cumulative trauma disorders (Fransson and Winkel, 1991; Pyykko et al., 1976; Radwin et al., 1987). The hand force may also have a synergistic effect with vibration exposure on anatomical structures, such as the vascular system, nerves and joints. The assessment of health and safety risk associated with exposure to hand-transmitted vibration, as defined in the current standard (ISO-5349-1, 2001), is solely based upon amplitude, frequency and duration of vibration exposure, while the contribution due to the hand force is ignored. Owing to the strong dependence of the hand–arm responses on the hand force, the need to measure the hand force has been recognized by many investigators, and an international draft standard (ISO/WD 15230, 2000) has been proposed specifically for the hand force measurement. The CEN-12349 (1996) and the recent revision of the ISO-5349-1 (2001) also emphasize the need for measurement of the hand force. These standards, however, provide no guidance regarding the techniques that can be used for the hand force measurement. This is most likely attributed to lack of a reliable measurement methodology.

Other studies have been carried to verify the dependence of the grip force and thus the contact force on the hand diameter and circumference (Li et al., 2010). A relationship was formulated to characterize the hand contact force on the basis of the linear combination of grip and push forces in conjunction with linear variations in the handle size (Welcome et al., 2004).

Eksioglu (2011) elaborated a prediction model based on anthropometric variables (maximum voluntary grip force, height, weight, body mass index, volumes of hand, forearm and whole arm, wrist range of motions, and a number of other hand-arm dimensions), to predict the endurance time of grip-force.

Numerous studies have focused on the methodologies of the interactions between cognitive actions, efforts and osteoarticular diseases and have been developed various methods for the quantification of risk and the weight of each action. One method is to compile a check list which expresses a degree of risk through the weighting of individual gestures making up the overall operation and the force estimated by the operator. In recent years (Camillieri et al., 2011) there has been a line of research aimed at developing tools that can provide measurements of the effort, with the aim of replacing subjective evaluations from a panel of professionals interviewed during the action. The provision of a kit (Romano et al., 2011) consisting of a shear equipped with sensors made it possible to map the efforts made by hand in order to evaluate both the overall effort to that produced by single muscle compartments.

The present work intends to investigate the influence of anthropometric factors on the force exerted to the handle of two different models of shear.

Material and methods

Experimental tests were conducted in the laboratory on branches from two specialized vineyard sites one in Torre de' Roveri (BG) in northern Italy and one in Viagrande (CT) in Sicily in southern Italy during winter pruning on a group of 10 healthy volunteers subjected to tests using two cutting shears (fig.1) types on the market, mainly different for characteristics of the handle and blade. The testers were aged between 20 and 40 years.

Figure 1. The two tested shears

The experimental plan provided for a randomized block design and considered four cultivars, one cultivar taken in both locations, two diameters on which to cut (3-6mm, 9-12mm), with three repetitions of the same condition.
Data were collected from six areas of the hand of all eight participants. Laboratory tests were carried out with a cutter equipped with sensors that transmitted during cutting, the forces exerted by six different areas of the hand from operators.
For the measurements have been used sensors described in a precedent article (Romano et al. 2010).
The end of such sensors is positioned so as to coincide with the point of contact of the fingers of the operator with the handles of the pruning shears during the operation in order to investigate the efforts related to the contact point with the handle of the index, middle and ring fingers and the palm corresponding to three zones closet to the thumb.
Were recorded for each individual: age, weight, height, length, width, thickness and volume of the hand. During the cutting operation has been detected effort of the hand in terms of intensity and duration by a shear equipped with sensors.

Figure 2. The kit used to record forces exerted on shears.

Results

The sensors installed on the handles of the shears have given to the PC via wireless, for each cut made, the records of the force curve from the six areas of the hand of every participant tested.

The files related to acquisitions were processed to extract from each cut, the peak occurred for each part of the hand under investigation.

In this way we could have, for each test condition, the peak in N and the length of the cut in seconds, or the time elapsed between the first stimulus recorded by the sensor exceeds the threshold of 1.5 N and his return to that value. This time interval was considered active to cut the branch. Table 1 and fig. 3 show maximum force recorded during tests.

Table 2. Mean of maximum Force recorded (Letters refer Duncan's test)

Cultivar	Peak of Force (N)	Endurance (s)
0 Cabernet CT	19.97 c	1.12 c
1 Moscato di Scanzo	12.75 a	0.81 a
2 Merlot CT	15.45 b	0.89 b
4 Cabernet BG	18.46 c	1.13 c
5 Merlot BG	14.33 b	0.91 b
Diameter	Peak of Force (N)	Endurance (s)
1 (3-6mm)	7.52 a	0.61 a
2 (9-12mm)	24.86 b	1.34 b

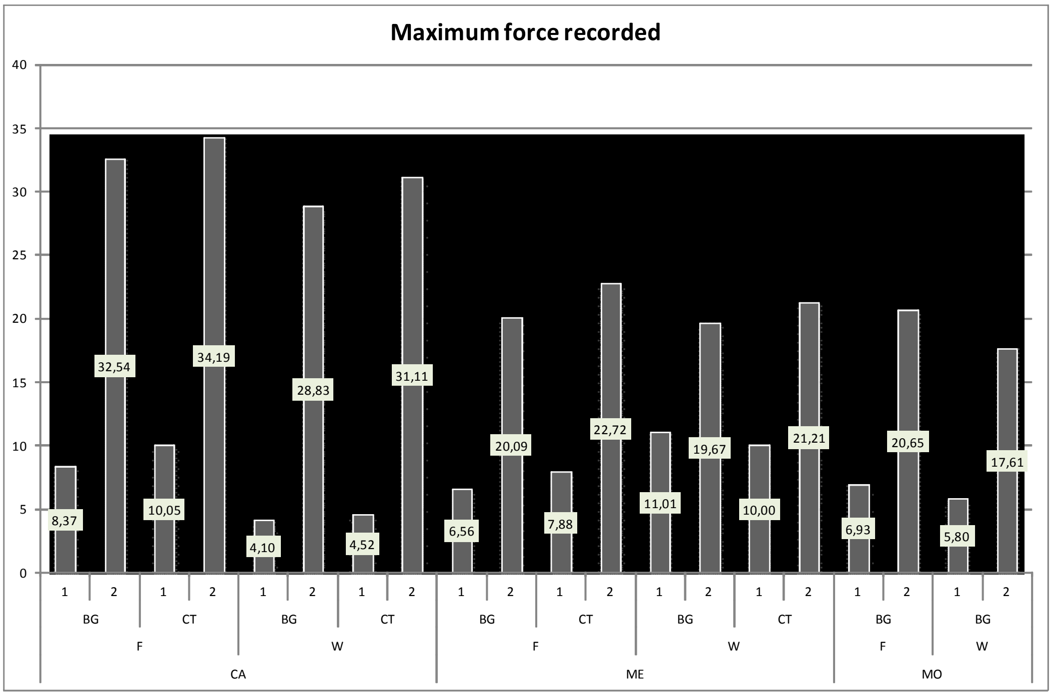

Figure 3. Maximum force (N) recorded in all conditions

Processing has been designed to check whether the observed variables could describe the force exerted to perform the act of pruning, through the method of principal components (PCA) using the test conditions as statistical units. The most of the variability is explained by

the first two principal components, as many as 55.14% from the first and 49.31% by the second. The other main components are essentially negligible summed explain less than 8%.
The result is summarized in the graph biplot (fig. 4) where vectors of the variables are arranged in orthogonal way, those relating to the anthropometric parameters highlighting significance for the second component, while those relating to the characteristics of the materials under test and the values of show significant strength is measured against the first component.
The anthropometric vectors have thus distributed the statistical units in seven parallel bands, while inside the bands, the composition of all the other carriers have deployed across the values collected.

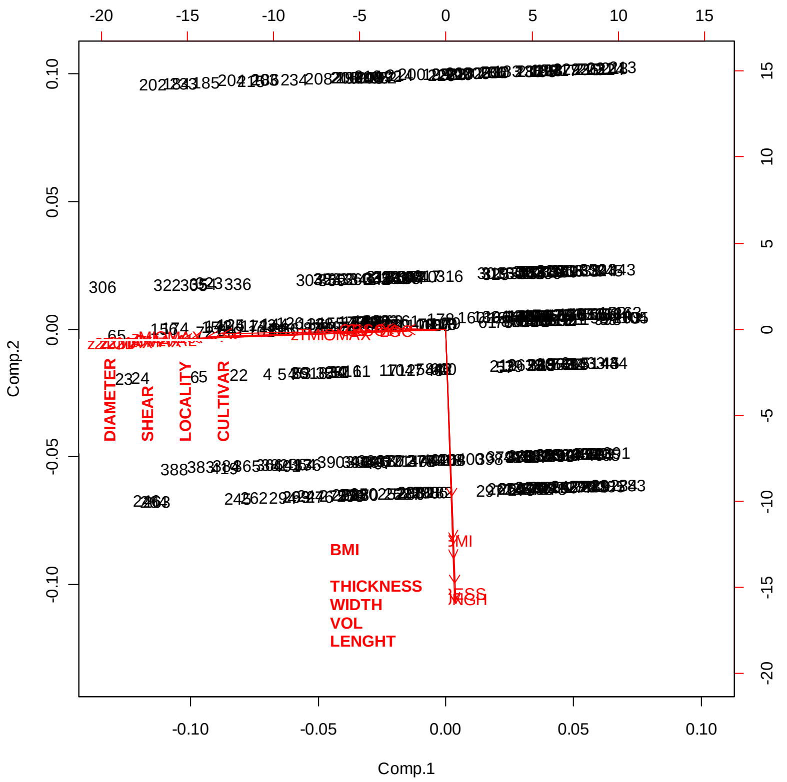

Figure 4. Biplot of all variables vectors on the maximum force recorded

It was necessary therefore to develop two additional splitting vectors in PCA always feature the maximum force recorded.
The first report considered only the vectors of the test conditions (shear type, Cv, Location, diameter of branch) in respect of the maximum force recorded.
Also in this case the first two components may explain the distribution of values. In the biplot graph (Fig. 5) the vectors of the ten variables are clearly distinct subgroups, particularly distinguished by the vector diameter 5 right and 5 left, while the transverse separation into 5 groups is operated by the vector cultivars and locations.
The vector of the shear has contributed, though less than the diameter, the location of points on the graph. The force vector, of course, leads the points that have required more effort on the left side of the graph.

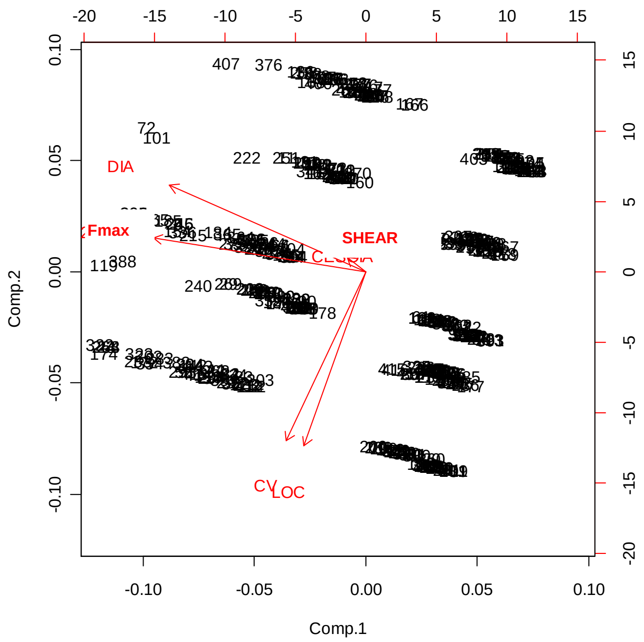

Figure 5. Biplot of test condition vectors on the maximum force recorded

Biplot graph (Fig. 6) of anthropometric vectors, for the first component, shows that the selected sample of testers to be submitted in test were sufficiently distinct, so that the vectors of the of anthropometric parameters can distribute the items in test in a perfectly distinct into seven subgroups, consisting to testers trial exactly. In particular, the vectors that have had more influence in the distinction of these seven subgroups were the weight vector and the vector width of the palm.

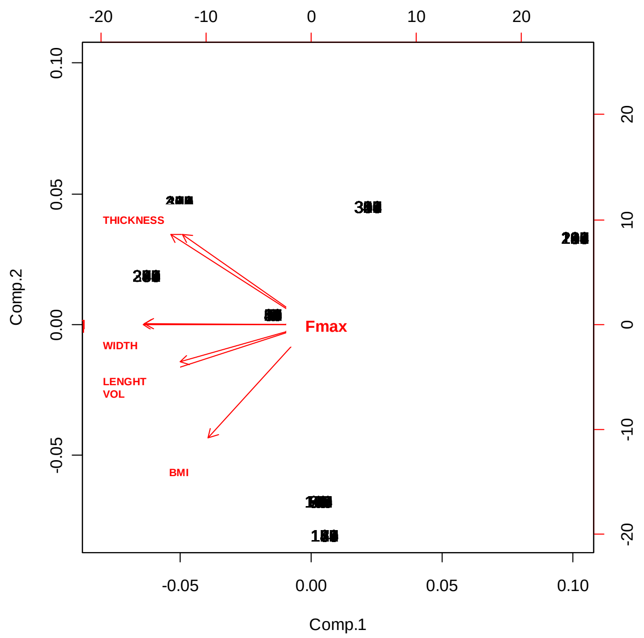

Figure 6. Biplot of anthropometric parameters vectors on the maximum force recorded

For testing the effects of vectors taken into account with respect to the force values recorded, it was necessary to prepare an analysis of variance (ANOVA). It has thus been detected with a significance p-value <0.001 for the influence of the type of shears used, for the cultivar, for the diameter of the branch, and for the location of withdrawal. The anthropometric parameters does not have instead demonstrated significant influence of the values of maximum force recorded.

Conclusions

It may be concluded that from the analysis performed on the data collected, it is confirmed the correct experimental approach, the random components of the testers team is highlighted by the PCA, a marked distinction by anthropometric parameters and ANOVA has not shown any significance for repetition of conditions. The force values recorded through the kit of acquisition have been influenced by the test conditions including the dominant vector which was the diameter of the shoots. However none of the anthropometric parameters has been discriminating element in the development of the force applied to the handle of the shears, or more precisely the effect of the anthropometric parameters has been covered by the effect of the factors under test.

For a validation of what was found would be appropriate, having already done the analysis of the effect of other variables, the development of other cycles in the laboratory tests on a larger number of testers and also considering different age groups.

Acknowledgements

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References

Camillieri, D., Romano, E., Bonsignore, R., Rapisarda, V., Schillaci, G., 2011. Hand Forces Measured During Vine Shoot Cutting. Proceeding of XXXIV CIOSTA CIGR V Conference 2011, 120-121.

Eksioglu M., 2011. Endurance time of grip-force as a function of grip-span, posture and anthropometric variables. Int. Jour. Of Industrial Ergonomics, 41, 401-409.

Fransson, C., Winkel, J., 1991. Hand strength: the influence of grip span and grip type. Ergonomics 34 (7), 881–892.

Gurram, R., Rakheja, S., Gouw, G.J., 1995. A study of hand grip pressure distribution and EMG of finger flexor muscles under dynamic loads. Ergonomics 38 (4), 684–699.

Hartung, E., Dupuis, H., Scheffer,M., 1993. Effects of grip and push forces on the acute response of the hand-arm system under vibrating conditions. Occupational and Environmen-

tal Health64, 463–467.

Li, K., Hewson D.J., Duchêne, J., Hogrel, J.Y., 2010. Predicting maximal grip strength using hand circumference. Manual Therapy, 15, 579-585

Miyashita, T., Miura, H., Futatsuka, M., 1990. Hand-arm vibration, noise, temperature and static load: an experimental study of peripheral circulation while operating chain saws. Kurume Medical Journal 37, 73–83.

Pyykko, I., Farkkila, M., Toivanen, J., Korhonen, O., Hyvarinen, J., 1976. Transmission of vibration in the hand-arm system with special reference to changes in compression force and acceleration. Scandinavian Journal of Environment and Health2, 87–95.

Radwin, R.G., Armstrong, T.J., Chaffin, D.B., 1987. Power hand tool vibration effects on grip exertions. Ergonomics 30 (5), 833–855.

Reidel, S., 1995. Consideration of grip and push forces for the assessment of vibration exposure. Central European Journal of Public Health3, 139–141.

Romano, E., Bonsignore, R., Camillieri, D., Conti, A., Schillaci, G., 2010. Evaluation of Hand Forces During Manual Vine Pruning. Proceeding of International Conference Ragusa SHAWA 2010, 94.

Romano, E., Camillieri, D., Bonsignore, R., Schillaci, G., 2011. Perceived stress and measured forces in vineyard pruning. Proceeding of XXXIV CIOSTA CIGR V Conference 2011, 120-121.

Roquelaure, Y., Gabignon, Y., Gillant, J.C., et al., 2001. Transient hand paresthesias in vineyard workers ofChampagne. Am. J. Indust. Med. 40, 639–645.

Roquelaure, Y., Dussolier, G., Dano, C., et al., 2002. Biomechanical strain on the hand–wrist system during grapevine pruning. Int. Arch. Occup. Environ. Health 75, 591–595.

Wakula, J., Beckman, T., Hett, M., et al., 2000. Ergonomic analysis of grapevine pruning and wine harvesting to define work and hand tools design requirements. Occup. Biomechanics 2, 151–161.

Welcome, D., Rakheja, S., Dong, R., Wu, J., Z., Schopper, A., W., 2004. An investigation on the relationship between grip, push and contact forces applied to a tool handle. International Journal of Industrial Ergonomics, 34, 507–518.

ISO-5349-1, 2001. Mechanical vibration—measurement and evaluation of human exposure to hand-transmitted vibration—Part1: General requirements. International Organization for Standardization.

ISO-10819, 1996. Guide for mechanical vibration and shock–hand–arm vibration-method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand. International Organization for Standardization.

ISO/WD 15230, 2000. Definition and guidelines for the measurement of the coupling forces for operators exposed to hand-arm vibration. ISO/TC 108/SC 4/WG 3.

Topic 1

“WMSDs Work Related Musculo-Skeletal Disorders”

Poster Presentation

The sunrise of agricultural ergonomics and safety studies in Italy and in Europe

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Abstract
Far away to be a complete work of all the first agricultural ergonomics and safety studies in the fifties-seventies, aim of this paper is to focalize the occupational hazard problems that the researches faced at the beginning of the agricultural mechanization spread in Italy and in Europe to let a comparison with today's situation.
European literature, standard and Italian laws of the period around 1955-1975 have been collected and examined.
Specific occupational hazards have been considered with the different approach of the researchers, with the aim to highlight safety and ergonomics operator risks in function of the mechanization level and machines spread in the different agricultural and forestry fields.
It is obvious that during the time the technology and the mechanization level have mainly displaced the axis hazards from mechanical and electrical risks to others (as physical and chemical). Among all the machines, the tractor was and is the main responsible of all the injuries type.
Unfortunately, in Italy a common risk was present at the beginning of the spread agricultural mechanization among the farms as well as nowadays: the machine overturn (66% of fatal injuries in 1957 and around 90% in 2009).

Keywords: agricultural safety, history, origins of safety studies

Introduction

It is a matter of the fact that in the safety and ergonomics studies the agriculture has always been 'one step behind'.

The ergonomics and safety history in agriculture has been articulated itself along a difficult path, because of the different work and environment conditions, not comparable with the factories workplaces. The mechanization of the rural areas improved both the productivity and the work organization in the farms, especially in the North of the world after the Second World War, but at the meantime injuries and occupational hazards increased.

As shown in figure 1, in Italy from 1950 to 1958 an increase of power in agriculture of 336% produced there an increase of injuries of 590%. It is not difficult to understand the reasons of these increments: as Alcide de Gasperi observed at the beginning of the fifties: '… When I started my first trips by plane, I had the real perception of the Italian landscape. From the height I was aware of the fields slope and fragmentation (more than looking at the maps), real obstacles to a safe rural mechanization in our country.' (Eboli, 1960).

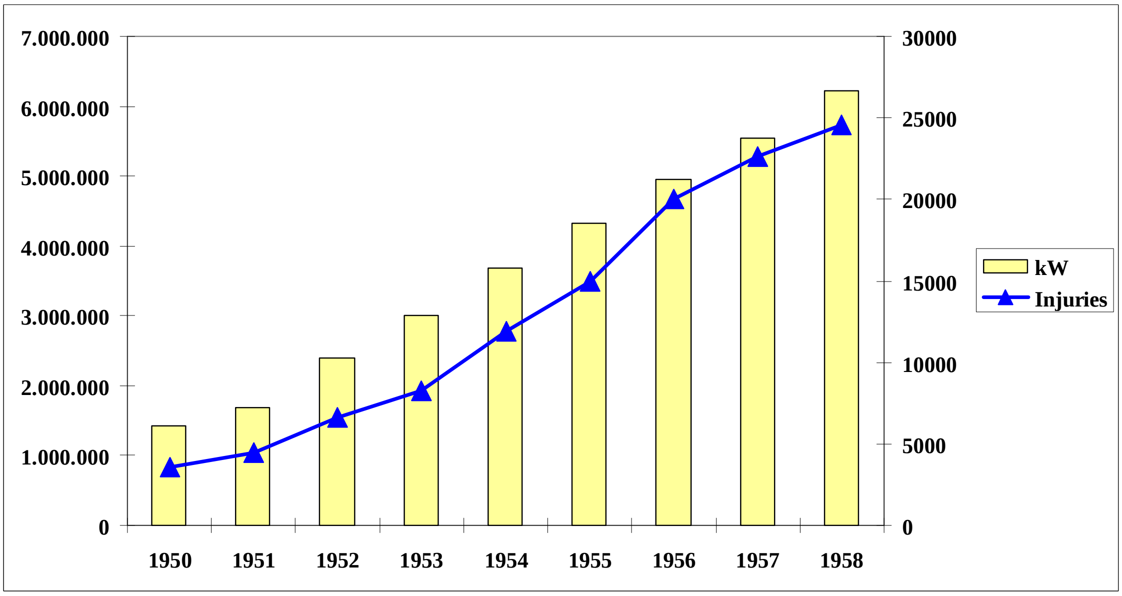

Figure 1. Agricultural mechanization power and injuries trend in Italy in the period 1950-1958 (Stefanelli, 1960)

From the legislation point of view, the concern for the protection of workers' health and safety against occupational risks resulted in the enactment of legislation, aimed at monitoring the hazards at work and establishing the relation between the worker and his work environment. Starting from fifties, new legislation was enacted in the United States, United Kingdom, France, Italy and Sweden, to mention a few countries. Standards for controlling the various hazards were established and varying policies and programmes for educating and training workers started to be instituted at national, institutional and workplace levels.

In Italy, for example, in 1955 was launched the first organized law concerning: 'Standards to prevent work injuries' (D.P.R. 547/55). In this law safety indications to be applied in the workplaces were given, as well as for tools, operating machines, transport vehicles, farm plants, tanks, electric plants and dangerous materials.

Another law interesting the agricultural tractor in Italy was the D.P.R. 393/59 (Testo Unico del Codice della Strada): in the article number 29 the agricultural machines division was mentioned. In other following articles the homologation rules for tractors, agricultural trailers and self-propelled machines were described.

Materials and methods

European literature, standard and Italian laws of the period around 1955-1975 have been collected and examined. Specific occupational hazards have been considered with the different approach of the researchers, with the aim to highlight safety and ergonomics operator risks in function of the mechanization level and machines spread in the different agricultural and forestry fields.

Results

In Italy, since the second half of the fifties the researchers' interests on agricultural safety topics increase (Gasparetto, 2002).

First studies in Italy are due to Robiony (Robiony, 1952), Carena (Carena, 1955) and Stefanelli (Stefanelli, 1956), concerning agricultural injuries analysis and tractor behaviour in sloped areas.

In 1957, a national conference concerning:' The adaptation of agricultural machines to the man' occurs. The interesting thing in the title is the approach of the machine adaptation to the man, instead of the man adaptation to the machine (as the first industrialized rules advised). We are at the sunrise of ergonomics studies in agriculture.

In these years, the Italian institution which has the work to promote, to develop and to spread the injury and occupational hazard prevention is ENPI (Ente Nazionale per la Prevenzione degli Infortuni), officially founded in 1938, but reorganized in 1952.

In January, 1960, ENPI organizes the: 'National Conference on Safety in Agricultural Mechanization', to let researchers, public and private institutions, manufacturers, technicians and agricultural operators to meet and to discuss the emergent problems in this topic.

During the conference it is underlined that the 66% of fatal injuries are caused by tractors overturns: this problem has never been solved (in 2009 tractor overturn fatal injuries will reach the sad amount of 90%).

Another discussion argument is the electric energy utilization in agriculture: in these years the electric grid is used to operate different agricultural machines (press, threshing machine, animal feed machine, chain-saw, agricultural product transformation machineries,) using an electric engine, at fixed or not fixed point.

Another interesting discussion point is the agricultural manufacturers responsibility,'…Who are responsible to eliminate, or when it is not possible, at least to reduce the danger' (we find these same words in the 2010 'Machine Directive'). In the case when a residual danger exists, the manufacturer: '…should provide pictures (universally understandable) near the danger point to emphasize the danger, as well as users manuals to explain machine functions and how to prevent injuries'. This is the start of pictograms and user manual spread use.

Because of the tractor overturn problem, many studies are carried out during sixties to avoid the problem, as the motor wheels misalignment, the indicator devices for transversal slope, the clutch detach, the stop of the fuel input when reaching a gradient limit. Professor Stefanelli's studies on tractor stability concerns proposals on machine auto-stability and first protective devices against the overturn risk (Stefanelli, 1966).

At the same time a Sweden researcher observes that in worst slope and street conditions car drivers are more protected than tractor drivers because they have a 'roof' over the head: it is the first beginning of the protective cabs design (Gasparetto, 1968). In 1964 ASAE (American Society of Agricultural Engineers) starts to study new ROPs (Roll Over Protection systems) and cab types, to prevent injuries caused by tractors overturn (Lamouria et al., 1964).

The years of the passive safety instead of the active safety are starting, crossing from the anti-injury point of view to the ergonomics one.

At the beginning of sixties ENPI publishes the first manuals on safety in the agricultural work place, considering the double rule of the farmers: agricultural operators and mechanics, for the machines maintenance (Androni et al., 1960). In these booklets a deep discussion is dedicated to the cardan joint protection (figure 2).

At the end of the sixties, the first organized ergonomics studied starts.

Several authors have defined ergonomics as both a multi-disciplinary and inter-disciplinary field of study concerned with the application of science, research and technology to improve the working and living conditions of workers. Thus, ergonomics as a field aims to prevent work injuries and illnesses so as to increase efficiency and productivity at the workplace. The application of knowledge in ergonomics involves understanding the relation of man-machine and environment. Training in ergonomics provides one with knowledge for proper planning of workplace systems at the design stage and also furnishes a criterion for selecting the right worker for the job or the possibility of fitting the job to the worker. However, the application of ergonomics principles varies with the country and with the work site, depending both on the levels of industrialisation and mechanisation, and field application. Within developed countries in Europe, the United States and Eastern countries, ergonomics has evolved from other fields such as physiology, psychology, anatomy and engineering. Consequently, most authors or specialists in ergonomics are trained in many fields.

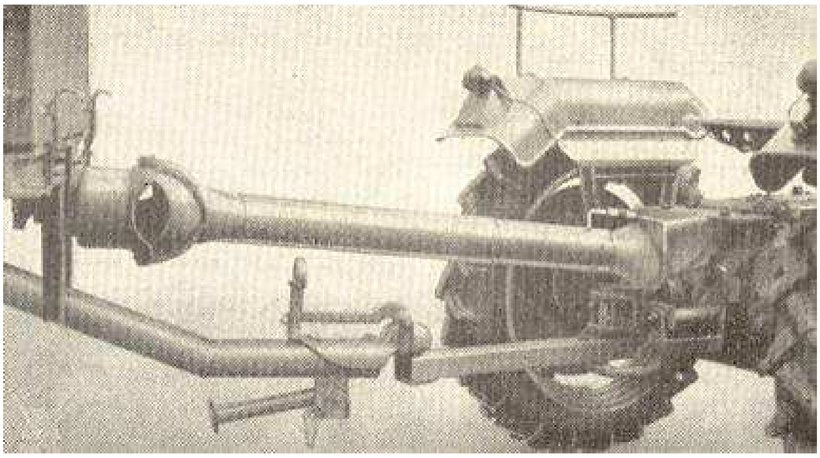

Figure 2: The first system of cardan joint protection (Androni et al., 1960)

In the sixties-seventies, one of the most considerable Institutions for the ergonomics studies is the NIAE (National Institute of Agricultural Engineering, Silsoe, Great Britain) which deeply studies specific topics, such as agricultural machines cabs, suspended cabs projects, tractor vibration and corresponding human answer, workplace environment, ergonomics principles in agricultural mechanization. In 1971 Matthews e Knight publish the manual: 'Ergonomics in agricultural equipment design'. It is divided in 2 sectors ('Ergonomics principles of design' and 'Application of ergonomics design principles to specific equipment') and describes both ergonomics definitions and their applications to the agricultural machines (how to design an ergonomics agricultural machine, workplace position and layout, control design, instrumentation and display, workload, noise, vibration, climate, light and comfort, dust, repetitive works).

Anthropometric studies are in the meantime carried out, based on ISO (International Standard Organisation) data to optimize the driver workplace (figure 3).

Also agricultural manufactures are involved in the ergonomics debate in these years: in 1975 FIAT (Fabbrica Italiana Automobili Torino) publishes a paper on: 'Human physiology applied to agricultural tractor' (Wyss, 1975), treating the machine access, driver stress studies (cardiac cost and oxygen consumption) and whole body vibration. In the same years, John Deere publishes the first computer aid simulation studies to realize new ROPs (Smith, 1977).

Concerning this sector, various are the contributes for better ROPS studies (with also figures on projects and field tests, as NIAE does in 1970s). The interest of NIAE concerning ROPs is due to the fact that in Great Britain, starting from 1970, September, manufacturers are obliged to mount protective chassis on tractors. Whitaker in 1975 adds a new interesting component, without which ROPs are useless: the seat belts (Whitaker, 1975).

Also in Italy we find studies concerning the tractor overturn studies and the ROPs promotion (Buldini, 1975; Robiony, 1981). In this field, UMA (Utenti Motori Agricoli) starts to awaken public opinion at National and European level to find a common strategy for safety devices mounted on agricultural machines, especially ROPs (UMA, 1975).

The machine-man interaction is deeply studied abroad (Stikeleather, 1975; Zander, 1974) as well as in Italy. Piccarolo in 1976 publishes a paper concerning ergonomics and work organization during the mechanic milking. In a different context, tractor and grape harvesting machines are considered, especially concerning rollover risks, rebounds on connection system with the tractor (due to the charge) and slip problems on the system tractor-trailer (Cappello e Cioni, 1978, Cioni, 1978).

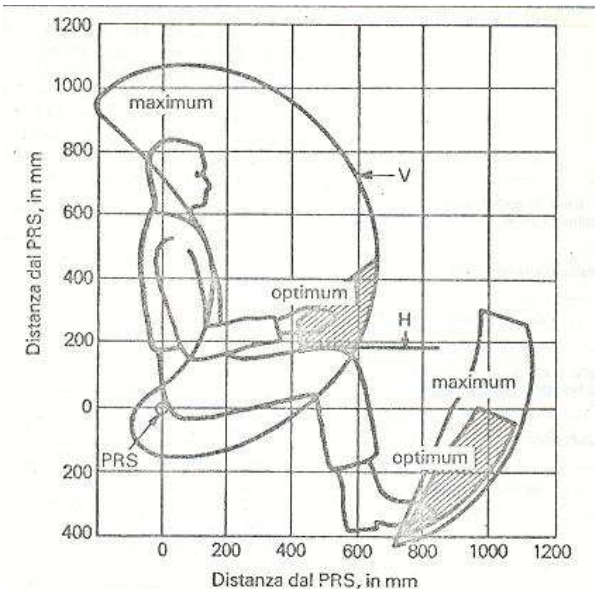

Figure 3: Lateral views of operator’s movements while he is driving the tractor. V is the vertical plane passing through the shoulder, H is the horizontal plane of action area, SRP is the seat reference point.

Conclusions

Also if at national level almost each European country has its laws concerning safety (but not concerning agricultural machines and places), up to 1973 none European compulsory standard on agricultural and forestry machinery safety is available. Only voluntary standards, such as ISO and OECD, are in force.

In 1974 the EEC publishes the first directive concerning tractors. We must wait until 1989 (1996 in Italy) to have the first EU ‘Machine Directive’, the 98/37/CE, which has large objectives, better determined by specific standards, attaining a high level of safety, both in design and manufacturing, whilst also allowing for technical innovation.

A long time is elapsed since the first ergonomics and safety studies: nowadays we have specific standards and laws, also concerning the agricultural machines and workplaces. Injuries are diminished in the agricultural context, but certain professional diseases are increased (muscular and skeleton disorders *in primis*) and certain injuries continues to be fatal (tractor overturns).

Laws are necessary, but it is also necessary to think over this more than 50 years old sentence: '… one of the fundamental aspects … is the confirmation of some moral principles which can be summarized in the respect of the human being in his double meaning of physical and moral person …' (Stefanelli, 1960).

References

Androni D., Tanzarella G, Zammarano E. 1960. Note di prevenzione infortuni per conduttori di trattrici e macchine agricole. Edizioni ENPI.

Bottoms D.J. 1975. Progettazione del posto di guida della trattrice. Gli studi del NIAE. Macchine e Motori Agricoli, 33(11), 205-211.

Buldini F. 1975. Cabine di sicurezza: indispensabili 'implementi' per trattrici ed altre macchine agricole. Macchine e Motori Agricoli, 33(12), 109-117.

Burks. G.E. 1966. A better ride for the tractor operator, Caterpillar Tractor Co., 11. Internationaler automobiltechnischer Kongress, Munchen, 12-16 June 1966.

Cappello C., A. Cioni. 1978. Problemi connessi con la sicurezza del lavoro in agricoltura con riferimento al settore viticolo. Atti del Convegno: 'Prevenzione dei rischi professionali in agricoltura'. Perugia, 7 settembre 1978.

Carena A. 1955. Macchine e infortuni in agricoltura, Humus.

Cioni A. 1978. Problemi della sicurezza del lavoro connessi con la raccolta dell'uva. Estratto dagli Atti del Convegno Nazionale sulla Vendemmia Meccanica in Italia. Firenze, 22 giugno 1978. 39-48.

De Vecchi Pellati N. 1960. Il ribaltamento della trattrice. Atti del Convegno Nazionale sulla Sicurezza nella Meccanizzazione Agricola. ENPI. Bologna, 15-16 gennaio 1960. 157-166.

DPR 547/55. 1955. Norme per la prevenzione degli infortuni sul lavoro.

Eboli M. 1960. Sviluppo della meccanizzazione in agricoltura e relativo fenomeno infortunistico. Atti del Convegno Nazionale sulla Sicurezza nella Meccanizzazione Agricola. ENPI. Bologna, 15-16 gennaio 1960. pp. 21-38

Gasparetto E. 1968. Le cabine per le trattrici agricole. Macchine e Motori Agricoli, 1, 12-17.

Gasparetto E. 2002. La normativa nazionale e comunitaria per le macchine agricole. Atti del Convegno Nazionale AIIA: La sicurezza delle macchine agricole e degli impianti agro-industriali. Aspetti normativi, tecnici, ergonomici e anti-infortunistici. Alghero, 11-15 settembre 2002.

ISO/TC 127/SC2 3/WG4 5E. 1973. Human Physical dimensions of operators and minumim operator space envelope for earthmoving machinery.

ISO/TC 23/SC 3/WG4 5E. 1973. Proposal for Agricultural Tractor Seating Accomodation.

Lamouria L.H., Lorenzen C., Parks R.R. 1964. Design Criteria for a Driver-Safe Tractor Frame. Transaction of the Asae. 7(4), 418-419.

Mandriota A. 1960. Responsabilità dei costruttori di macchine agricole nella prevenzione degli infortuni. Atti del Convegno Nazionale sulla Sicurezza nella Meccanizzazione Agricola. ENPI. Bologna, 15-16 gennaio 1960. 322-324.

Materi M. 1960. L'impiego dell'energia elettrica in agricoltura e la prevenzione degli infortuni. Atti del Convegno Nazionale sulla Sicurezza nella Meccanizzazione Agricola. ENPI. Bologna, 15-16 gennaio 1960. 167-194.

Matthews J., Knight A.A. 1971. Ergonomics in Agriculture. Equipment Design. NIAE.

Matthews J. 1975. Ergonomics of Tractor Design with Regard to Work-place Environment. The Agricultural Engineer, 4(30), 102-111.

Piccarolo P. 1976. Aspetti ergonomici ed organizzativi della mungitura meccanica.

Piccarolo P., Calvo A. 2012. Sicurezza in agricoltura. Studi del prof. Stefanelli nel ventennio 1950-1970. Atti dell'Accademia dei Georgofili.

Rehkugler G.E., Kumar V., Davis D.C. 1976. Simulation of Tractor Accidents and Overturns. Transaction of the ASAE, 19(4), 602-613.

Robiony D. 1952. Sul determinismo degli infortuni da macchine agricole, Macchine e Motori Agricoli, 2, 18-24.

Robiony D. 1981. Il rischio da trattrici agricole. Macchine e Motori Agricoli, 39(4), 51-62.

Smith D.W. 1977. Computer Simulation of Tractor Ride for Design Evaluation. J. Deere Company. Off-Highway Vehicle Meeting and Exhibition. Milwaukee, September 12-15.

Stefanelli G. 1956. Sicurezza e stabilità trasversale delle macchine agricole su terreni declivi. Atti della Conferenza dell'Appennino Tosco-Emiliano.

Stefanelli G. 1960. Sviluppo e prevenzione degli infortuni nell'impiego delle trattrici agricole. Atti del Convegno Nazionale sulla Sicurezza nella Meccanizzazione Agricola. ENPI. Bologna, 15-16 gennaio 1960. 93-154

Stefanelli G. 1965. La prevenzione degli infortuni nella meccanizzazione delle aziende agricole collinari. Securitas, 6, anno 50, 31-73.

Stefanelli G. 1966. Aratura meccanica con una trattrice autostabilizzata e sicurezza di lavoro. Atti del Convegno per la sicurezza del lavoro nelle aziende agricole. ENPI. Grottaferrata, 24-26 marzo 1966.

UMA. 1975. Problemi di sicurezza delle macchine agricole. Telai di protezione. A cura della Direzione Centrale Tecnico Assistenziale, Ufficio Studi.

Zander J. 1974. Anthropometric Aspects of Work-Space Lay-Out on Selfpropelled Agricultural Machines. General Report III/A. International Workshop: Ergonomics Standards in Agriculture. Selfpropelled Agricultural Machines and Tractors. Potsdam, May 6 – 10.

Whitaker J.R. 1975. Analisi degli incidenti per ribaltamento con cabine di sicurezza. Gli studi del NIAE. Macchine e Motori Agricoli, 33(12), 55-58.

Wyss V. 1975. Fisiologia applicata al trattore agricolo. Ricerche per la sicurezza e il confort. Relazione presentata dalla Direzione Igiene e Sanità della Fiat Trattori al Convegno ENPI: "Problemi di sicurezza e di prevenzione degli infortuni nelle macchine destinate alla lavorazione dei terreni dell'alta e media collina. Perugia, 2 settembre 1975.

Evaluation risks of biomechanical overload during the manual vineyard pruning by using measured values of the effort

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Abstract

Several analytical methods have been developed to determine and quantify the risk from exposure to biomechanical overload of the upper limbs. The subjective estimates of the force applied by the workers during the assessment of muscle-skeletal risk exposure in the vineyard manual pruning appear critical. Some recent research has been carried out using a sensorized scissor to obtain measures of the handling effort used, in place of the estimates expressed by the workers (Schillaci et al., 2010; Romano et al., 2010). This research proposes a preliminary study of an experimental methodology in order to replace subjective opinions with instrumental values obtained by using electromyography (EMG) in assessing the risk of muscle-skeletal overloading of the upper limbs during manual vineyard pruning.

The OCRA method (Colombini and Occhipinti, 1996, 2005) is the procedure recommended by the international standard (ISO 11228-3) for risk assessment from overload due to upper limbs repetitive movements. The Borg CR10 scale is usually used to evaluate the subjective perception of the strain in relation to the amount of the strain. In this research, we have used the results of laboratory tests that used EMG performed by a sample of pruners on different vine cultivators with different branch diameters and with different scissors. Using the surface EMG it was possible to highlight the actions taken by each muscles involved in the technical actions. The measurements of the EMG acquired were compared with the measurements of the MVC (maximum voluntary contraction) on the activity and the subject examined.

From the data processing recorded during the laboratory operations, represented by percentage of intensity compared to the relative MCV, a value was obtained for the strength for each muscle analyzed during the activity and for an intensity scale of the strength. The values of the "strength" acquired have been used to calculate the risk through the OCRA index. The results obtained were compared with the workers opinions about the subjective perception of the strain and with the results of previous research (Schillaci et al., 2010; Romano et al., 2010). The EMG tests have shown the involvement of the muscular districts involved giving new ideas about the risk assessment in pruning operations.

Keywords: OCRA Method, EMG, MCV

Introduction

There are several analytical methods developed to determine and quantify the risk from exposure to biomechanical overload of the upper limbs. They are often criticized because they are considered unsuitable to accurately quantify the exposure to the risk factors.

It appears critical the subjective estimate of the force applied by the workers during the assessment of muscle-skeletal risk exposure in the vineyard manual pruning. Some recent researches have been carried out using a sensorized scissor to obtain measures of the handle effort to be used in place of the estimates expressed by the workers *(Schillaci et al., 2010; Romano et al., 2010).*
This research proposes a preliminary study of an experimental methodology in order to replace the subjective opinions with instrumental values obtained using electromyography (EMG) in assessing the risk of muscle-skeletal overloading of the upper limbs during vineyard manual pruning.

Methods
The OCRA method *(Colombini and Occhipinti, 1996, 2005)* is the procedure recommended by the international standards EN 1005-5 and ISO 11228-3 for the risk assessment from overload due to upper limbs repetitive movements.
The Borg CR10 scale is usually used to evaluate the subjective perception of the strain in relation to the amount of the strain.
Furthermore, the OCRA methodology allows different procedures for the evaluation of the "strength" as an estimate of the external force by using dynamometers and the estimate of the internal force through the surface electromyography (EMG).
In this research, we have used the results of laboratory tests using EMG (*Romano et al., 2012*) performed by a sample of pruners on three different vine cultivars (*Cabernet, Merlot, Moscato*) with twodifferent diameters of the branches (<5 mm / 8-12mm) andwith two different scissors (*Fig. 1 and Fig. 2*).

Fig. 1 – Scissor F

Fig. 2 - Scissor W

Using the surface EMG it was possible to highlight the actions taken by each muscles involved in the technical actions.
The measurements of the EMG acquired were compared with the measurements of the MVC (maximum voluntary contraction) on the activity and subject examined.
From the data processing recorded during the laboratory operations, represented by percentage of intensity compared to the relative MCV, a value was obtained for the strength for each muscle analyzed during the activity and for an intensity scale of the strength. The values of the "strength" acquired have been used to calculate the risk through the OCRA index. The results obtained were compared with the workers opinions about the subjective

perception of the strain and with the results of previous research (*Schillaci et al., 2010; Romano et al., 2010*).
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
The table below (Tab. 1) shows the data processing obtained during the cutting tests as compared to their MVC percentage for different cultivars. On this specific occasion, since we wanted to try an experimental methodology, we have been working with only average values.

Tab. 1 – Level (%) with respect to MCV

Scissor F	**37.09**
Cabernet	**47.22**
diameters <5 mm	25.14
diameters 8÷12mm	69.29
Merlot	**31.29**
diameters <5 mm	22.16
diameters 8÷12mm	40.41
Moscato	**28.43**
diameters <5 mm	20.86
diameters 8÷12mm	36.00
Scissor W	**28.12**
Cabernet	**34.74**
diameters <5 mm	19.19
diameters 8÷12mm	50.29
Merlot	**24.78**
diameters <5 mm	15.37
diameters 8÷12mm	34.18
Moscato	**21.56**
diameters <5 mm	12.82
diameters 8÷12mm	30.31
Total	**32.60**

The values measured in the cutting trials were converted into Borg scores in relation to the average strains. Starting from the values obtained, we can get the Borg scores so that to calculate the risk of upper limb biomechanical overload via the OCRA method..The results are not conclusive, but at facevalue, it seems to be a strict connection with the results of previous study whereas values of stress obtained from laboratory tests using sensorized scissors (instead of the estimation expressed by operators) were used to calculate the OCRA index. (*Schillaci et al, 2010; Romano et al, 2010*).

Conclusions and perspectives

This research proposes a preliminary study of an experimental methodology in order to replace subjective opinions with instrumental values obtained by using electromyography (EMG) in assessing the risk of muscle-skeletal overloading of the upper limbs during manual vineyard pruning.

Finally, this research wants to become the starting point of the good practice of choosing a work tool from the beginning (in this case, a pair of pruning scissors) that meets the ergonomic criteria so that to reduce the ergonomic risk.

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References

Colombini D., Occhipinti E., Fanti M. 2005. *Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti*. Collana Salute e lavoro, Franco Angeli Editore.

Romano E., Bonsignore R., Camillieri D., Caruso L., Conti A., Schillaci G. 2010. *Evaluation of Hand Forces During Manual Vine Branches Cutting*. International Conference Ragusa SHWA2010 - September 16-18, 2010 Ragusa Ibla Campus- Italy.

Romano E., Camillieri D., Longo D. , Rapisarda V., Schillaci G. 2012. *A clinical test to research objective values of effort during manual pruning.* International Conference RAGUSA SHWA2012 September 3-6 2012 Ragusa - Italy

Schillaci G., Balloni S., Bonsignore R., Camillieri D., Romano E. 2010. *Hand forces during manual vine branches cutting.* Atti su CD-Rom del Third International Congress on Mountain Viticulture, Castiglione di Sicilia (Italy), 12/14 maggio.

Schillaci G., Balloni S., Caruso L., Camillieri D. 2010. *Risk due to repetitive movements in manual vineyard pruning*. Atti su CD-Rom del Third International Congress on Mountain Viticulture, Castiglione di Sicilia (Italy), 12/14 maggio.

Schillaci G., Bonsignore R., Camillieri D., Romano E. 2010. *Assessment of the "Strain" Parameter in the Calculation of the Biomechanical Risk Index as Regards the Upper Limbs in Vineyard Manual Pruning.* International Conference Ragusa SHWA2010 - September 16-18, 2010 Ragusa Ibla Campus- Italy.

First evaluation of the risk from repetitive movements in greenhouse nurseries: annual cycle and multitask analysis

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Abstract

The aim of this study is to develop an appropriate methodology in the field of musculoskeletal risk in horticultural greenhouse nurseries in eastern Sicily. During the ordinary activities in the nursery the tasks have been identified and for each task was evaluated exposure to risk through the OCRA Checklist. This study represents the starting point of a national work group made up of doctors and experts in the field of work place organization, whose aim is to put together simplified methods (database, software) that permit the monitoring and management of the risk of biomechanical overloading in such complex situations as cultivation in protected environments.
Measurements were carried out in different nurseries located in eastern Sicily. The first part of the work consisted of the identification of the main sectors and tasks characterizing the activities in the (plant) nursery. The measurements were conducted using the technique of breaking the work into its elementary phases. The tasks were later filmed. Subsequently, the use of the OCRA checklist made it possible to assess the postural requirement (shoulder, elbow, wrist, hand) for each task and to quantify the biomechanical overloading of the upper limbs.
There are several activities in the nurseries where there is a risk of biomechanical overload due to repetitive movements of upper limbs and the manual movement of loads. In nurseries also, seasonal work influences the risk and the exposure of workers to biomechanical overloading depending on the task carried out and varies also for the same task according to the intensity and duration.
The observations confirmed that nursery activities show a considerable risk and should be considered throughout the annual cycle.

Keywords: checklist OCRA, database, work organization

Introduction

Plain nursery activity in the horticultural field play an important rule and position itself on the top of the agricultural supply-chain. In Italy, the production regards about 3000 companies located in an area of 1900 hectares. The world of companies is quite heterogeneous: it includes either small family-run business either big companies that invest in a high capital commitment, up to date technology and manpower.
Because of the technology used, capital invested, considerable use of labour, employee management and risks at work, the production process of a nursery can be considered similar in type to that of industry.
Given that the demand for labor per hectare is more than 15000 hours and 2300 working

days, there are so many people involved in these activities and many are the risks to health and safety of workers.
In the last few years, work related musculoskeletal disorders (WMSDs) have increased at a dramatic rate and the plain nursery activity is involved in this kind of risk as well.
There are several activities in the nurseries where there is a risk of biomechanical overload due to the repetitive movements of upper limbs and the manual movement of loads. Moreover, in spite of the great development of the mechanization in the past decade, there are still jobs– especially in greenhouses – that require manual works.
In nurseries, seasonal work influences a lot the kind of job and the condition of work: the exposure of workers to biomechanical overloading depends on the task carried out and varies also for the same task according to the intensity and duration (*Colombini et al., 2007).*
The exposure of workers to biomechanical overloading depends on the task carried out and varies even for the same task according to the intensity and duration (*Colombini et al., 2007*).
In some horticultural nurseries of Eastern Sicily sectors and tasks have been isolated with the aim to develop a suitable study about the musculoskeletal risk. For each task has been valuated the exposure through the OCRA Checklist.
This study represents the starting point of a national work group made up of doctors and experts in the field of work organisation, whose aim is to put together simplified methods (database, software) permitting the monitoring and management of biomechanical overloading risk in such complex situations as cultivation in protected environments.

Methods

Measurements were carried out in different nurseries located in Eastern Sicily.
The first part of the work consisted of the identification of the main sectors and tasks characterizing the activities in the (plant) nursery. The measurements were conducted using the technique of breaking the work into its elementary phases. The tasks were later filmed. Examination of the video films made it possible to find or confirm information about frequency, stereotypic nature and posture.
Following this, a preliminary assessment was made of the biomechanical overloading risk to the upper limbs by means of the OCRA checklist (*Colombini et al., 2005*).
The assessment was limited to the intrinsic exposure risk, that is to say just to the risk arising from frequency, use of force, incongruous postures and the stereotype nature of the work, considering a typical day of work for 8 hours with 2 rest breaks.

Results

The main sectors are sowing, processing sector, cultivation, logistics and grafting (*Fig. 1*).
Tasks such as manual sowing, transplanting and spraying involve frequently repeated technical actions and prolonged incorrect posture maintained for at least half the time or for almost the whole time (Tab.1).

Fig. 1 – Work stations where repetitive operations are carried out

Tab. 1 – OCRA Checklist score calculation

Work stations	Frequency	Force	Posture	Addit.	Checklist OCRA DX	Checklist OCRA SX
Manual sowing with seated operator	9	0	11	0	20	
	9	0	11	0		20
Manual sowing with standing operator	9	0	11	0	20	
	9	0	11	0		20
Automatic sowing Substrate loading	4	1	6	0	11	
	0	0	1	0		1
Automatic sowing Container loading	0	0	5	0	2	
	0	0	5	0		2
Automatic sowing Sowing check	9	0	11	1	21	
	4,5	0	11	1		17
Automatic sowing Stacking	0	1	2	1	3	
	0	1	2	1		3
Transplanting	7	0	6	0	14	
	7	0	6	0		14
Spraying	9	0	15	0	16	
	4,5	0	4	0		4
Tube transfer	2,5	0	5,5	0	5	
	2,5	0	5,5	0		5

Conclusions and perspectives

The study represents the first step in realizing a database of tasks carried out in horticultural greenhouse nurseries with risk scores for each task. This database would be particularly useful considering that nursery activity is characterized by different tasks with significant differences in intensity and duration. These tasks involve the rotation – sometimes frequent – of workers.
Since the intrinsic values of the activities that characterize the nursery have been calculated in advance, the software allows you to instantly calculate the level of annual exposure by simply entering the duration of the tasks performed every month, throughout the year.
It is of fundamental importance that the nursery organization should include the gathering of information regarding the tasks carried out and the work times for homogeneous groups of workers.

References

Calvo A., 2008. Musculoskeletal disorders (MSD) risks in forestry: a case study to propose an analysis method. In: International Conference Ragusa SHWA2008 "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems", 2008, September 15-17, Ragusa, Italy.

Cecchini M., Colantoni A., Massantini R., Monarca D., 2010. The risk of musculoskeletal disorders for workers due to repetitive movements during tomato harvesting. J. Agric. Saf. Health 16(2), 87-98.

Colombini D., Occhipinti E., Fanti M., 2005. Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti. Collana Salute e lavoro, Franco Angeli Editore.

Colombini D., Occhipinti E., Hernandez A., Alvarez E., Montomoli L., Cerbai M., Fanti M., Ardissone S., Ruschioni A., Giambartolomei M., Sartorelli P., 2007. Repetitive movements of upper limbs in agriculture: set up of annual exposure level assessment models starting from OCRA checklist via simple and practical tools. In: International Conference on Agriculture Ergonomics in Developing Countries, AEDeC, 2007, November 26-29, Kuala Lumpur, Malaysia.

Douphrate D., Rosecrance J. 2010. Industrialization of Dairy Operations: Ergonomic Implications. In: International Conference Ragusa SHWA2010 - September 16-18, 2010 Ragusa Ibla Campus- Italy "Work Safety and Risk Prevention in Agro-food and Forest Systems", p. 10-13.

Montomoli L., Colombini D., Fanti M., Ruschioni A., Ardissone S., Sarrini D., Coppola G., Sartorelli P., 2008. Risultati degli studi e dell'analisi del rischio clinico da sovraccarico biomeccanico degli arti superiori in viticoltura e olivicoltura. In: VI Congreso Internacional de Prevención de Riesgos Laborales, 2008, May 14–16, A Coruňa, Spain.

Montomoli L., Ardissone S., Colombini D., Fanti M., Ruschioni A., Sartorelli P. 2010. Task Analysis, Risk Assessment and Clinical Evaluation of Work Related Muscoloskeletal Disorders in Viticulture and Olive Culture Farming. In: International Conference Ragusa SHWA2010 "Work Safety and Risk Prevention in Agro-food and Forest Systems", 2010, September 16-18, Ragusa Ibla Campus, Italy, 304-310.

Pressiani S., Colombini D., 2010. Risk Assessment in Plant Nursery Characterized By Several Working Task With Annual Turnover. In: International Conference Ragusa SHWA2010 "Work Safety and Risk Prevention in Agro-food and Forest Systems", 2010, September 16-18, Ragusa Ibla Campus, Italy, 114-120.

Schillaci G., Caruso L., Balloni S., Camillieri D. 2011. I rischi da sovraccarico biomeccanico nelle attività del vivaio orticolo. Convegno di Medio Termine dell'Associazione Italiana di Ingegneria Agraria. Belgirate, 22-24 settembre 2011.

Literature review: application of the OCRA method in agriculture and agro food activities

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Abstract

The aim of this paper is to implement revisions of the application of the OCRA method in the Italian agriculture and agro-food sectors available in the literature. In Italy risk assessment for biomechanical overload of the upper limbs due to repetitive movements, is performed using the OCRA method (OCcupational Repetitive Actions, Colombini and Occhipinti, 1996, 2005).

The OCRA method has been reported and used in a number of consensus documents and National and International guidelines. Nowadays it is used as a method of assessing risk caused by repetitive movements of the upper limbs and is recommended by the technical standards ISO 11228-3 (Ergonomics - Manual handling - Part 3: Handling of low loads at high frequency) and EN 1005-5 (Safety of machinery - Human physical performance - Risk assessment for repetitive handling at high frequency).

The OCRA method is based on two procedures: the OCRA Checklist, which is used for a preliminary estimation of operator exposure, and the OCRA index, which is used for a more detailed assessment of risk. The latter procedure offers significant standards for the preventive and redesigning measures of the work processes that follow. In Italy, in reference to the activities of the agriculture and agro-food sector, the OCRA index has been applied only recently in viticulture, peach growing, olive cultivation, cheese and mozzarella production, tomato harvesting and sorting, crop spraying in greenhouses and in the floral and nursery sectors.

From the review of the articles it appears that the spread of the OCRA method in the agricultural sector has been hampered by the difficulties of applying the method in a context that is very different from the industrial and manufacturing sectors.

Furthermore, it should be noted that this method has its complexity and for its application it requires a lot of time and adequate training of the evaluator.

The surveys carried out show the necessity to undertake a suitable study of organization in agricultural workplaces and to adapt to some specific aspects that the method shows in the agricultural compared to other sectors.

Keywords: repetitive movements, checklist, evaluation of risks

Introduction

In Italy risk assessment for biomechanical overload of the upper limbs due to repetitive movements, is performed using the OCRA method (Occupational Repetitive Actions, *Colombini and Occhipinti, 1996, 2005*).

The OCRA method, which has been updated and modified over the years, it is currently recommended by ISO 11228/3, EN 1005-5, and its application is mandatory in Italy in the assessment of such risks (*Art. 28 D. Lgs. 81/08*).

The OCRA method was originally designed for industry, or for workstations whereas the

rhythm of work is imposed by a process that doesn't require a worker.
Afterwards, it has been adopted in the industrial workstations just like in the handcraft industry.
In the agricultural sector, the spread of the OCRA method was hampered by many factors:

- the lack of attention demonstrated by the employers in the evaluation of risk,
- the lack of agriculture sensibility against the ergonomics of workstations,
- some general difficulties in the application of the method in a field that , as is well known, it's very different from industry and manufacturing.

The aim of this paper is to implement revisions of the application of the OCRA method in the Italian agriculture and agro-food sectors available in the literature.

Review

The first who applied the OCRA method in the agricultural sector were Colombini and Occhipinti along with an international workgroup, in 2007(*Colombini et al., 2007*).
In some companies involved in the wine and apricot cultivation, that are located in Tuscany, Piedmont and Marche, they have done a preliminary evaluation of the risk of biomechanical overloading of the upper limbs using the checklist OCRA.
The first survey results, though still preliminary and concerning a small case-report, evidenced that pruning and harvesting are characterized by a medium or potential high risk of exposure (red and purple area).
In the same year, the OCRA index is applied to evaluate the risk of workers involved in the manual cernit during the mechanical harvesting of tomatoes (*Cecchini et al., 2007, 2010*). The cernit are then sorted by electronic sorters, which select the tomatoes according to their colour. The job is normally carried out by the workers and is characterized by a high frequency of action.
In 2008, they proposed a model able to calculate the OCRA method in the analysis of the multiple tasks risk exhibition with a weekly, monthly and annual basis rotation (*Colombini et Occhipinti, 2008*). The study reveals that pruning and harvesting some fruits (kiwi, peach, apricot) exhibits workers to a medium or potential high risk of exposure (red and purple area).
Another study (*Montomoli et al., 2008*), shows the results of the Risk of biomechanical Overloading of the Upper Limbs in wine and olive cultivation.
In viticulture, workers are exhibit to a medium or potential high risk of exposure depending of the variety and the type of cultivation (vines low, medium and high).
In olive growing, the results of studies showed a clear biomechanical overload mainly due to awkward postures maintained during the work.
In the same year, however, the Italian Agricultural Engineering published two papers about the risk evaluation by biomechanical overload using the OCRA method. In the first paper, the evaluation of the risks involved repetitive manual tasks in the dairy sector during the production of mozzarella cheese, butter and cheese (*Porceddu and Rosati, 2008i*). The study reveals that the activities at greatest risk are the preparation and packaging of the ricotta cheese and butter. Moreover in 2008, were presented other studies where the OCRA method was applied to define the biomechanical risks borne by employees chemical spraying in greenhouses (*Balloni et al., 2008*). In the survey, movements were evaluated by repeated cycles movement of the shoulder complex - arm - wrist, and emerged a sensitive risk (red area) for workers who conventionally carry between rows and holding the spears used for treatments.
In 2009, were obtained the preliminary results of the biomechanical overloading of the upper

limb risk in the floral and nursery industry (*Pressiani, 2009*), whose final results have been presented in 2010 (*Pressiani and Colombini, 2010*).
This research was performed taking into account the whole annual cycle of work and the various activities carried out by workers in a nursery floriculture. A homogeneous group of workers was followed by a precise criteria selection: kind of tasks, the equipment used, seniority and experience. To complete the picture of biomechanics demand requested by workers, postural commitment of each phase of the activity was evaluated as well. Since the activity in the nursery is characterized by high seasonality, the analysis shows that aiming to study the real exposure of workers, it must be done an analysis of its actual exposure all over the year.
In 2009, surveys were conducted in the greenhouse with the aim of verifying the muscular - skeletal risk using the OCRA Index related to the execution of the pruning in tomato plants (*Schillaci et al., 2009).* The tests showed the containment of the muscle - skeletal upper limb risk exposure, obtained through the use of a mobile caterpillar platform with adjustable working surface (this solution allows to lower the arms below the shoulders while working) and, moreover, it showed that it’s compulsory emphasizing the influence of the working frequency on the value of OCRA Index (*Schillaci et al., 2010*).
In 2009, were presented some preliminary assessments of risk due to repetitive movements during manual pruning in vineyards using the OCRA Index. (S*chillaci et al., 2009*). Testing different cultivars have led to a higher average OCRA scores, confirming what emerged in other studies (*Montomoli, op cit*).
During the winter pruning cuts, follow on from one another rapidly and with a certain regularity, it requires in addiction, for certain cuts, a major use of the force.
About the force, experimental tests were carried out using sensorised secateurs, that it is specially made (*Romano et al, 2010*), with the aim to identify the effort and avoiding the use of the Borg scale (*Schillaci et al., 2010*).
Regarding to the frequency of the cuts, it was highlighted the existence of variations that depend on the work context and the organization of work and responding to curves determined (*Schillaci et al., 2010*).
In 2011, were performed studies about workers involved in the production of cheese to evaluate biomechanical overloading of the upper limb risk in an Italian agro-food factory (*Monarca et al., 2011; Cecchini et al., 2011*). Risk assessment has been done using the OCRA checklist and taking into consideration the principle phases of the productive cycle. Moreover, they have tried to find the devises for lowering the risk for those workers employed in salting and in the cutting.
In 2011 were presented assessments about the seasonal workers subjected to the biomechanical overloading risk in the work of vegetable nurseries (*Schillaci et al, 2011*), employees during the she-asses milking (*Camillieri et al., 2011*) and involved in other vegetable grafting works (*Colantoni et al. 2011*).
In 2012 were presented assessments about the seasonal workers subjected to the biomechanical Overloading risk being involved in the harvest (strawberry, tomato, watermelon, apples, kiwifruit, lettuce) (*AA.VV. 2012*), workers involved in animal farms (*Ardissone, 2012*) and in dairy farms as well (*Martini, 2012*).

Conclusion and perspectives

From the review of the articles it appears that the spread of the OCRA method in the agricultural sector has been hampered by the difficulties of applying the method in a context that is very different from the industrial and manufacturing sectors. Furthermore, it should be

noted that this method has its complexity and its application requires a long time-frame such as an adequate training of the evaluator.
Surveys show the need to undertake a suitable study of organization in agricultural workplaces with the aim to adapt it to some specific aspects that the method has showed in the agricultural sector and compared with other sectors, generally characterized by highly structured positions and therefore very different from the farming ones.
Studying the real exposure of the worker means first of all analyzing its actual exposure throughout the year and for this reason, the objective of future research in agriculture is to obtain a greater number of epidemiological data and create simple tools and practical to estimate the risk calculation of risk (software, databases).

Reference

AA.VV. 2012. *Il sovraccarico biomeccanico nelle attività di raccolta dei lavoratori stagionali in agricoltura. Indicazioni per la sorveglianza sanitaria.* In: VI Seminario Internazionale EPM, 14-15 giugno 2012, Milano, Italia.

Ardissone S. 2012. *L’esposizione al rischio da movimenti ripetitivi in compiti settimanali discontinui. L’esperienza in un allevamento avicolo*. In: VI Seminario Internazionale EPM, 14-15 giugno 2012, Milano, Italia.

Balloni S., Caruso L., Conti A., Schillaci G., Valentino M., Loreto C., Fenga C., Rapisarda V. 2008. *Use of a Helmet Endowed with Forced Ventilation and Air Filtration Devices in Greenhouse Application of Agrochemical Treatments Using an Innovative Prototype of Self-Propelled Sprayer Vehicle*. In: International Conference RAGUSA SHWA 2008, September 15-17, Ragusa, Italy.

Camillieri D., Failla S., Restuccia A., Schillaci G., 2011. *First Results of Ergonomics Studies of Donkey Machine Milking*. In: XXXIV CIOSTA CIGR V Conference 2011.

Camillieri D., Rapisarda V., Balloni S., Schillaci G. 2010. *The Effect of Task Frequency on the Risk of Biomechanical Overloading of the Upper Limb During Tomato Binding*. In: International Conference Ragusa SHWA2010, September 16-18, Ragusa, Italy.

Colombini D., Occhipinti E. 2008. *I modelli di calcolo del metodo OCRA nell’analisi del rischio espositivo a più compiti a rotazione settimanale, mensile, annuale*. Seminario EPM, giugno 2008.

Colombini D , Occhipinti E., Hernandez A., Alvarez, E. Montomoli L., Cerbai M., Fanti M., Ardissone S., Ruschioni A., Giambartolomei M., Sartorelli P. 2007. *Repetitive movements of upper limbs in agriculture: set up of annual exposure level assessment models starting from OCRA checklist via simple and practical tools*. In: International Conference on Agriculture Ergonomics in Developing Countries, AEDeC 2007

Cecchini M., Bedini R., Colantoni A., Menghini G., Monarca D. 2011. *Repetitive movements of upper limbs and risk of musculoskeletal disorders for workers during the cheese production in an Italian agro-food factory*. Irish Meeting on Agriculture Occupational Safety and Health. Dublino (Irlanda), 22-24 agosto 2011.

Cecchini M., Colantoni A., Massantini R., Monarca D. 2010. *The risk of musculoskeletal disorders for workers due to repetitive movements during tomato harvesting*. Journal of Agricultural Safety and Health. 16(2), p. 87-98.

Cecchini M., Massantini R., Monarca D. 2010. *The ergonomics analysis tools for the assessment of the risk of musculoskeletal disorders due to the repetitive movements of the upper limbs of the workers employed in agriculture*. In: Towards environmental technologies. Clermont-Ferrand (FRANCE), 6-8 september 2010.

Colantoni A., Monarca D., Cecchini M., Bedini R., Marucci A., Pagniello B. 2011. *The risk of musculoskeletal disorders for workers due to repetitive movements of upper limbs during the vegetable graft in greenhouses*. In: International Symposium on Vegetable Grafting. 3-5 Oct. 2011, Viterbo – Italy.

Martini M. 2012. *Valutazione del rischio ergonomico in un’azienda produttrice di latticini*. In: VI Seminario Internazionale EPM, 14-15 giugno 2012, Milano, Italia.

Monarca D., Cecchini M., Colantoni A. 2011. *Working posture, repetitive movements of upper limbs and risk of musculoskeletal disorders for workers during the cheese production in an Italian agro-food factory*. Vienna (Austria), 29 giugno - 1 luglio 2011.

Monarca D., Cecchini M., Colantoni A. 2007. *Il rischio di affezioni muscolo scheletriche per movimenti ripetitivi negli addetti alla cernita durante la raccolta del pomodoro da industria*. In: Convegno Nazionale AIIA. “Tecnologie innovative nelle filiere: orticola, vi. Pisa e Volterra, 5-7 settembre 2007, vol. 1, p. 88-91.

Montomoli L., Colombini D., Fanti M., Ruschioni A., Ardissone S., Sarrini D., Coppola G., Sartorelli P. 2008. *Risultati degli studi e dell’analisi del rischio clinico da sovraccarico biomeccanico degli arti superiori in viticoltura e olivicoltura*. Seminario EPM, giugno 2008.

Porceddu R., Rosati L. 2008. *Repetitive manual operations in the dairy sector: analyses and criteria for intervention*. Journal of Agricultural Engineering, Vol. XXXIX, n°1, march.

Pressiani S. 2009. *Risultati di studi organizzativi ed espositivi nelle serre: esempio di lavorazione con compiti multipli a ciclo annuale*. Seminario EPM Milano, giugno 2009.

Pressiani S., Colombini D. 2010. *Risk assessment in plant nursery characterized bi several working task with annual turnover.* In: International Conference Ragusa SHWA2010, September 16-18, Ragusa Italy.

Romano E., Bonsignore S., Camillieri D., Caruso L., Conti A., Schillaci G. 2010. *Evaluation of hand Forces During Manual Vine Branches Cutting*. In: International Conference Ragusa SHWA2010, September 16-18, Ragusa Italy.

Romano E., Bonsignore R., Camillieri D., Conti A., Schillaci G. (2010). *Evaluation of hand forces during manual vine pruning*. In: International Conference Ragusa SHWA2010, September 16-18, Ragusa Italy.

Schillaci G., Balloni S., Caruso L., Camillieri D. (2010). *Risk due to repetitive movements in manual vineyard pruning*. in: Third International Congress on Mountain Viticulture, Castiglione di Sicilia (Italy), 12/14 maggio. Valle d'Aosta: Cervim.

Schillaci G., Balloni S., Rapisarda V., Romano E., Bonsignore R., Camillieri D. 2009. *Valutazione del rischio da esposizione a movimenti ripetitivi degli arti superiori nella potatura manuale del vigneto*. In: IX Convegno Nazionale dell’Associazione Italiana di Ingegneria Agraria, Ischia Porto, 12-16 settembre.

Schillaci G., Bonsignore R., Camillieri D., Romano E. 2010. *Assessment of the "strain" parameter in the calculation of the biomechanical risk index as regards the upper limbs in vineyard manual pruning*. In: International Conference Ragusa SHWA2010, September 16-18, Ragusa Italy.

Schillaci G., Caruso L., Balloni S., Camillieri D., Romano E., Rapisarda V. 2011. *WRMSDs Assessment in Greenhouse Nursery*. In: XXXIV CIOSTA CIGR V Conference 2011.

Schillaci G., Romano E., Balloni S., Caruso L., Camillieri D. 2009. *Prestazioni di Piattaforme Semoventi Multifunzionali ad Azionamento Elettrico nelle Operazioni Ricorrenti in Serra*. IX Convegno Nazionale AIIA. Ischia Porto, 12-16 Settembre.

Risk evaluation of upper extremity musculoskeletal disorders among cheese processing workers: A comparison of exposure assessment techniques

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Abstract

The aim of this study was to evaluate the risk of developing upper extremity musculoskeletal disorders among workers employed in Pecorino Romano cheese production. A secondary purpose was to evaluate the agreement between two commonly used exposure assessment techniques in the risk evaluation, the OCRA Checklist and the Strain Index (SI). The most problematic work tasks were identified in the packing and production departments, while the curing operations shown the lowest risks. The two risk assessment methods provided similar results in situations with high risk, especially for tasks involving hand and wrist intensive movements.

Keywords: biomechanical exposure; exposure assessment; musculoskeletal disorders

Introduction

Musculoskeletal disorders affecting the back, neck and upper limbs are some of the most economically and socially detrimental occupational-related diseases in the European Union and North America (Solidaki et al, 2010; EU-OSHA, 2010). Physical risk factors such as high force exertions, high repetition rates, awkward postures and prolonged vibration have consistently been linked to the development of musculoskeletal back, neck and upper limb disorders (National Institute for Occupational Safety and Health, 1997; National Research Council and the Institute of Medicine, 2001). The risk of musculoskeletal disorders is reported to be quite high among workers involved in food production (Ghersi et al., 1997; Douillet and Aptel, 2000) where many tasks require high physical exertion, repetitive motions and awkward postures. In cheese processing, additional factors such as microclimates, environmental conditions and manual materials handling present additional musculoskeletal stressors (Colantoni et al., 2011).

Compensable occupational disorders caused by physical risk factors affecting the upper limbs, have been recorded particularly often in the manufacturing of food in France, Finland, Austria and United Kingdom (EU-OSHA, 2010). A number of risk exposure assessment methods have been developed with the aim of quickly and accurately identifying and quantifying the risk posed by a particular job task. Most of these methods are semi-quantitative observational techniques in which a trained ergonomist applies a rating system to work task variables (force exertion, repetition, frequency, etc.) associated with musculoskeletal disorders (Takala et al., 2010). Most risk assessment methods aim to generate a risk index / composite score that represents the nature, magnitude, and duration of exposure for specific job tasks. The score can subsequently guide job or process redesign (Takala et al., 2010; David 2005). Two commonly used observational methods designed for assessing risk of upper limb musculoskeletal disorders are the Occupational Repetitive Actions methods (OCRA) and the Strain Index (SI). The purpose of this study was to evaluate the risk of developing upper extremity disorders among workers producing sheep cheese using these two observational exposure assessment methods. A secondary purpose was to evaluate the agreement between the two assessments methods employed, the OCRA Checklist and the Strain Index (SI).

Methods

Exposure assessment

The OCRA Index, alongside its simplified counterpart, the OCRA Checklist, generates synthetic indicators of risk exposure, which consider four primary risk factors (repetitiveness, force, postures and movements, recovery period) and some additional issues (mechanical, environmental, organizational). The duration of each single factor is also considered, as well the overall duration of repetitive tasks per shift. OCRA methods have been applied in many types of manufacturing industries (Occhipinti and Colombini, 2005; Sala et al., 2008; Apostoli et al., 2004) and significant associations were reported between the concise index scores and prevalent musculoskeletal disorders of the upper limbs (Grieco, 1998).

The OCRA Index, designed for detailed risk assessment, is calculated as the ratio between the number of technical actions performed during the work shift and the recommended number of technical actions estimated for the specific task. The assessment procedure detailed in international standards (ISO 11128-3; EN 1005-5) is time consuming and requires well-trained observers (Takala et al. 2010). The OCRA Checklist is a simplified version of the OCRA Index and is a useful tool for the initial screening of work tasks to quickly identify the main risk factors and assess the potential risk exposure. The OCRA Checklist results in the sum of the partial scores assigned to each factor according to exposure characteristics and duration. The risk exposure level is considered nominal if the final score is less than 7.5, light when values are between 7.1 and 11.0, medium when values range from 11.1 to 22.5, and high if the score exceeds 22.5. Work tasks scored greater than 11.0 should be redesigned and improved.

The SI is a risk assessment method that assists in the identification of job tasks that may lead to the development of upper limb musculoskeletal disorders (Moore & Garg, 1995). Six task-related variables of the job are evaluated to determine the hazard rating or SI score. The six variables include: exertion intensity, duration of exertion per cycle, efforts per minute, wrist posture, speed of work, and duration per day. Each variable is described as one of five levels associated with verbal or numerical anchors. Each level corresponds to a specific multiplier value, and the SI score is the product of all six multipliers. Based on the epidemiologic literature, biomechanical models and professional opinion, the multiplier for exertion intensity has the greatest influence on the resultant SI score (Moore & Garg, 1995). Tasks with SI scores less than 3 are considered not hazardous (or safe); 3-5 indicates that the magnitude of risk is uncertain or low; 5-7 signals that the some known risk is present; and tasks with scores greater than 7 are considered hazardous and should be redesigned. Recently, some users have suggested that scores could be interpreted as either high risk (>6.1) or low risk (≤6.1) (Garg et al., 2012; Moore et al., 2006). Since 1995, multiple studies have demonstrated a cross-sectional association between hazardous SI scores and upper extremity disorders (Spielholz et al., 2008; Drinkaus, Bloswick, Sesek, Mann & Bernard, 2005; Moore & Garg, 1995), and a smaller number have shown the SI to predict MSD formation in longitudinal studies (Garg et al., 2012; Knox & Moore, 2001). The repeatability and reliability of the SI ranges from moderate to good (Takala et al., 2010).

Workplace study

The study was carried out in a cheese manufacturing facility that processes annually 40 ML of sheep milk. About 65% of this milk is converted in *Pecorino Romano*, a PDO (Protected Designation of Origin) hard cheese that weighs from 25 to 35 kg. The production line of pecorino Romano involves 45 workers out of the 130 factory permanent staff (180 during peak production periods).

The upper extremity workloads were examined for 21 cheese-processing tasks performed in the production, curing and packing departments. Data concerning working methods, organization, productive capacity, shift duration and break periods were determined by interviews and direct observation. Work tasks were video-recorded from two perspectives (grossly sagittal and frontal planes to the worker) and analyzed for five complete task cycles to quantify the primary ergonomic risk factors (duration, frequency, posture and force). Risk evaluation was estimated for each upper limb and all 21 work tasks using the OCRA Checklist and Strain Index methods. The correspondence between the risk levels scores according to OCRA Checklist and Strain Index are shown in Table 1.

Table. 1. OCRA Checklist and Strain Index risk level classification

	OCRA Checklist	**Strain Index**	
Safe	<7.5	<3	
Very low risk	7.6-11	3-5	
Low/medium	11-22.5	5-7	
High risk	>22.5	>7	

Results

The OCRA Checklist and SI risk assessments lead to the identification of the most hazardous work tasks, the critical factors contributing to risk within the tasks, and the usefulness of each assessment technique. The most problematic (highest risk) work tasks were identified in the packing and production departments, while the curing operations, which were recently improved with enhanced process automation, showed the lowest risk levels. The two risk assessment methods provided similar results in situations with well-defined risk (Figure 1), especially for high risk tasks involving hand and wrist intensive movements as in turning forms, dressing, coating, label application, and washing forms (Table 2).

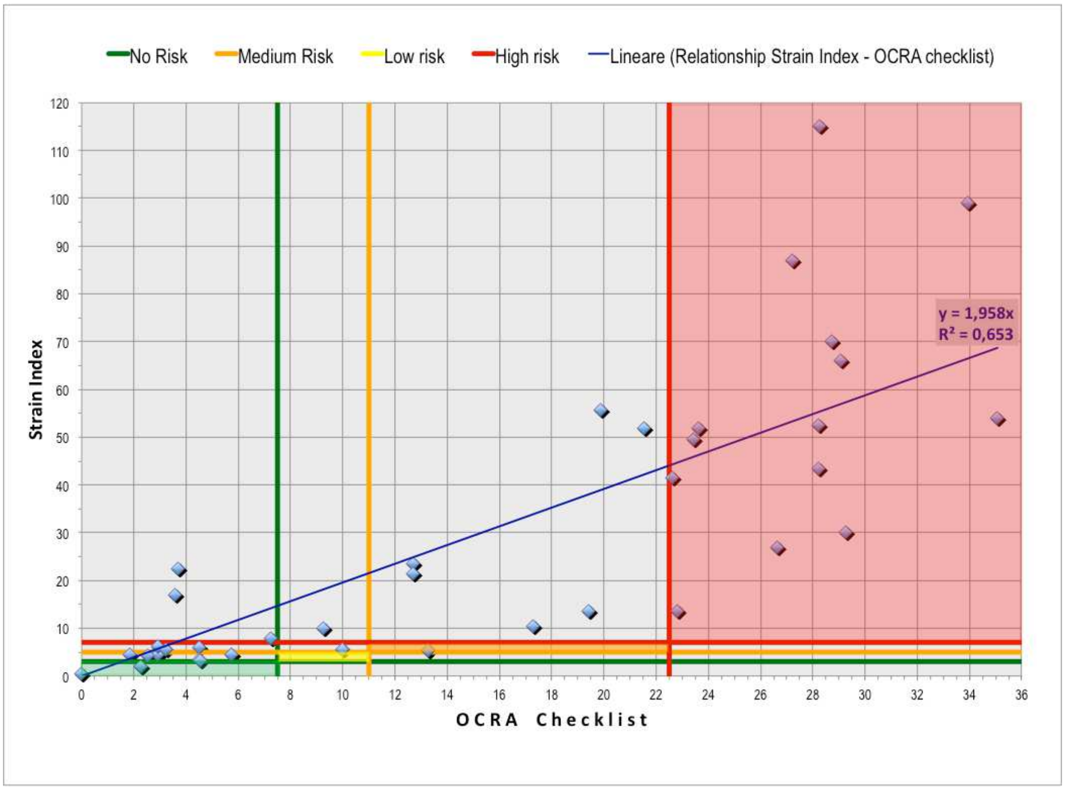

Figure 1. Distribution of risk exposure, for left and right arm, according to Strain Index and OCRA checklist scores. The lines discriminate the different risk levels (SI, horizontal; OCRA, vertical). Red, orange, yellow and green areas indicate the same risk range for both methods.

According to OCRA and SI evaluation, the critical factors in the production and packing departments were frequency of actions and awkward postures, specially referred to the hands, but SI shows an important contribution of intensity of exertion.

The level of risk identified by SI is higher than OCRA-CL in 57% of the total assessments. About 26% of the tasks were classified safe or with very low risk by SI (SI<5), while this percentage grew to 47% with OCRA analysis (score <11). The hazardous tasks, that need to be reorganized and redesigned, resulted respectively 57% and 33% of the total workplaces. The mean score for the hazardous classification was 43.1 (range 7.9-115) for the SI and 27.6 (range 22.6-35.1) for the OCRA Checklist. This difference is due to the risk factors and the relative weight considered in each method. Both concise indexes and sum scores are sensitive to the ratings assigned to the individual items (Takala, 2010).

Force is the variable that most influence OCRA and SI scores, which both consider the intensity of exertion (evaluated according to Borg CR-10 scale) and its duration over the work cycle. Comparable results were obtained for tasks that required high exertions, described by a Borg rating >4, while the result diverged when the force was classified as moderate or fairly light.

Repetitiveness is the second most heavily weighted variable for OCRA assessment, which considers over 70 actions/minute, while SI method ponder a limit of 20 efforts per minute. The limit of 20 efforts per minute for the SI may underestimate the weight of this assessment variable in jobs with high frequency of exertions (Moore et al., 2012). In our study almost

half of the examined tasks exceeded this limit, particularly those performed in the packing department.
Another difference between the two methods concerns the contribution of awkward postures to determine the final score. SI considers only the posture of hand and wrist, while OCRA assesses movements of the arm, elbow, wrist and type of handgrip.
Additionally, the OCRA method weighs the effective duration of each posture, so that some hazardous posture maintained for short periods do not affect the final level of risk for a specific task.

Table. 2. Evaluation of the workload on upper limbs according to Strain Index and OCRA Checklist

Dept	Work tasks	Arm	OCRA checklist	Strain Index
PRODUCTION	Draining/pressing curds	Right	5.8	4.5
		Left	5.8	4.5
	Loading moulds	R	10.0	5.5
		L	10.0	5.5
	Removing moulds	R	2.9	4.5
		L	2.9	4.5
	Wrapping plastic-moulds	R	28.7	70.0
		L	19.9	55.7
	Turning forms	R	28.2	52.5
		L	28.2	43.5
	Inserting marking band	R	21.6	51.8
		L	23.6	51.8
	Washing sheets	R	29.3	30.0
		L	2.6	4.2
CURING	Removing plastic moulds	R	9.3	10.1
		L	7.3	7.9
	Collecting plastic moulds	R	4.5	6.0
		L	4.5	3.4
	Entry forms salting machine	R	2.9	6.2
		L	3.6	17.0
	Loading salting boards	R	3.3	5.6
		L	4.6	3.2
	Entry washing-salting machine	R	27.2	87.0
		L	19.4	13.5
	Exit washing-salting machine	R	3.7	22.5
		L	1.9	4.5
PACKING	Bagging cheeses	R	13.3	5.4
		L	13.3	5.4
	Under vacuum bagging	R	12.7	23.6
		L	12.7	21.4
	Stacking forms on pallets	R	2.3	1.9
		L	2.3	1.9
	Label application	R	22.8	13.5
		L	17.3	10.5
	Cheese coating	R	35.1	54.0
		L	0.0	0.4
	Dressing	R	28.3	115.0
		L	29.1	66.0
	Washing forms	R	33.9	99.0
		L	26.6	27.0
	Boxing grated cheese	R	23.4	49.5
		L	22.6	41.6

Conclusions

The exposure to upper limbs risk factors (extreme posture, repetition, high muscle loads) appears to be significant for workers involved in sheep cheese production. In the Pecorino Romano production line, due to the low level of automation, many tasks are still performed manually and sometimes require prolonged and intense physical efforts that can increase the occupational risk. The most problematic areas were identified by both OCRA and SI the packing and the production departments. The agreement between the two methods was partial in the curing department. The use of different methods in the assessment of risk for upper limb musculoskeletal disorders may contribute to a more comprehensive integration of risk attributed to critical job tasks.

The results of this study indicate the need of planning micro and organizational ergonomic interventions for reducing the risk exposure in cheese manufacturing. Among engineering measures, we have suggested 1) the use of adaptable height work surfaces for allowing employees to work in a neutral position, 2) the insertion of conveyor or roller belt between adjacent work areas and 3) the use of scissors lift for adjusting the height of material at waist level while loading/unloading forms from pallet. The cheese coating workstation requires a comprehensive redesign with the use of standalone equipment or, or as a temporary alternative, introducing a rotary platform for the placing the form.

An organizational improvement process needs to consider the recovery time from physically intense work through the planning of short rest breaks to interrupt those activities that involve risk factors (high repetition, forceful exertions, or awkward postures). According to the OCRA evaluation, a programmed interruption of 8 minutes every hour could lower the risk by approximately 40% in the most intensive tasks.

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References

Apostoli P, Sala E, Gullini A, Romano C, 2004. Analisi comparata dell'applicazione di quattro metodi per la valutazione del rischio biomeccanico dell'arto superiore. G Ital Med Lav Erg, 26(3) Suppl: 232-241.

Colantoni et al., 2011. Thermal discomfort for workers in the agro-food industry: an experimental survey in a milk processing plant. Irish meeting on Occup. Safety and Health, Dublin (Ireland) Aug 22-24.

Colombini D., Occhipinti E., Grieco A., 2002. Risk asessment and management of ripetitive movements and exertions of upper limbs. Elsevier Science, Amsterdam.

Colombini D., Occhipinti E., Fanti M., 2011. Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti. Franco Angeli, Milano. p.307.

David GC., 2005. Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. Occupational Medicine, 55:190–199

Douillet P. and Aptel M., 2000.Preventing MSDs: towards a global approach. European Agency for Safety and Health at Work, 3:4-10.

European Agency for Safety and Health at Work, 2010. OSH in figures: Work-related musculoskeletal disorders in the EU — Facts and figures. Luxembourg,p.184.

Garg et al., 2012. The Strain Index (SI) and Threshold Limit Value (TLV) for Hand Activity Level (HAL): risk of carpal tunnel syndrome (CTS) in a prospective cohort. Ergonomics, (55) 4:396–414.

Ghersi R., Cavallaro A.M., Lodi V., 1996. Movimenti ripetitivi degli arti superiori: risultati della valutazione dell'esposizione e dell'indagine clinica negli addetti ad un reparto di lavorazione di carni suine del modenese. La Medicina Del Lavoro, 87:657-673.

Grieco A., 1998. Application of the concise exposure index (OCRA) to tasks involving repetitive movements of the upper limbs in a variety of manufacturing industries: preliminary validations. Ergonomics, 41(9):1347-56.

Knox & Moore, 2001. Predictive Validity of the Strain Index in Turkey Processing. JOEM 5:451-462.

Moore J.S., Garg A., 1995. A proposed method to analyze jobs for risk of distal upper extremity disorders. AIHA Journal 56:443-458.

Moore J.S., Garg A., 2006. The validity and reliability of the Strain Index. In: 16th International Ergonomics Association world conference proceedings. Maastricht, the Netherlands, 10–14 July.

National Institute for Occupational Safety and Health, 1997. Musculoskeletal disorders and workplace factors: A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back, in: U.S. Department of Health and Human Services (Ed.).

National Research Council and the Institute of Medicine, 2001. Musculoskeletal disorders and the workplace: Low back and upper extremities. National Academy Press., Washington. D.C.

Sala E, Torri D, Apostoli P, 2008. Esperienze di applicazione della valutazione del rischio dale Linee Guida SIMLII sul rischio biomeccanico dell'arto superiore. G Ital Med Lav Erg, 30(3) Suppl: 20-25.

Solidaki et al., 2010. Work-related and psychological determinants of multisite musculoskeletal pain. Scand J Work Environ Health 36(1):54-61.

Spielholz P. et al., 2008. Reliability and Validity Assessment of the Hand Activity Level Threshold Limit Value and Strain Index Using Expert Ratings of Mono-Task Jobs. Journal of Occupational and Environmental Hygiene, 5: 250–257.

Takala. E., Pehkonen. I.,Forsman. M., Hanssonm G., Mathiassen. S.E., Neumann. P., Sjogaard. G., Veiersted. K.B., Westgaard R.H.,Winkel. J., 2010. Systematic evaluation of observational methods assessing biomechanical exposures at work. Scand J Work Environ Health 36(1):3-24.

A clinical test to research objective values of effort during manual pruning

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Abstract
The current rating for the determination of risk from biomechanical overload of the upper limbs during pruning operations with traditional shears, refers to quantifications methodologies which are based on estimates of subjective operators interviewed during operations. The OCRA method (Colombini and Occhipinti, 1996, 2005) is the procedure recommended by the international standards EN 1005-5 and ISO 11228-3 for the risk assessment overload due to repetitive movements of upper limbs.
This research was based on laboratory pruning tests monitored through a surface electromyograph. The pruning operations were performed by a sample of seven healthy operators who performed the cutting, always in the same position, on shoots collected by vineyards during the winter pruning. The branches were collected from four different cultivars of vineyards and were divided into groups of two diameters (<5 mm and 8-12mm). The electromyograph was monitored by medical personnel and acquisitions were saved for subsequent processing. The muscle activity was detected by EMG via surface electrodes placed on the skin of forearm muscle. In this case, the isometric situation is not too complex, and the number of muscles involved is small, especially as the biceps and brachioradialis muscles are involved in a synergistic way.
The processing of data collected during the operations conducted in the laboratory, allowed to observe the ability of the clinical test to read and interpret the effort made by the muscles of the arm of the pruner. The correlation between the peak values of muscular effort and the diameters of the branches was analyzed in order to have a dimensional confirmation. It was also developed an analysis of variance in order to statistically show significant influences of the factors considered during the test, on the results of muscular effort pointed out from medical records. These results have highlighted the involvement of affected muscle groups, providing new insights into the risk assessment of pruning.

Keywords: biomechanical overload, EMG, OCRA

Objectives
The current rating for the determination of risk from biomechanical overload of the upper limbs during pruning operations with traditional shears, refers to quantifications methodologies which are based on estimates of subjective operators interviewed during operations. The OCRA method (*Colombini and Occhipinti, 2005*) is the procedure recommended by the international standards EN 1005-5 and ISO 11228-3 for the risk assessment overload due to repetitive movements of upper limbs. The Borg CR10 scale is

usually used to evaluate the subjective perception of effort in relation to its intensity. These estimates are affected by subjectivity and therefore may vary greatly from one individual to another. Recent researches have been carried out using a sensorized scissor in order to obtain objective measures of the effort to be used in place of the projections expressed by the workers.
The OCRA method also allows different procedures for assessing the "strength" as the estimation of external force by means of dynamometers and the estimation of internal strength through clinical trials such as surface electromyography (EMG), which assesses the electrophysiological degree of activation of muscles. This research aims to examine the reading skills of magnitude of effort performed by the upper limbs during pruning operations performed in the laboratory under different conditions for the possibility of substitution of subjective values with instrumental values in risk assessment.

Methods
This research was based on laboratory pruning tests monitored through a surface electromyograph (Fig. 1). The pruning operations were performed by a sample of seven healthy operators who performed the cutting, always in the same position, on shoots collected by vineyards during the winter pruning. The branches were collected from four different cultivars of vineyards and were divided into groups of two diameters (<5 mm and 8-12mm).
The electromyograph was monitored by medical personnel and acquisitions were saved for subsequent processing.

Fig.1 – Electromyograph during the cutting of branches in the laboratory

The muscle activity was detected by EMG via surface electrodes placed on the skin, above flexor and extensor carpi. So peak values of maximum muscular effort and the duration of the signal coming from the muscles during the cut were measured (Fig. 2).

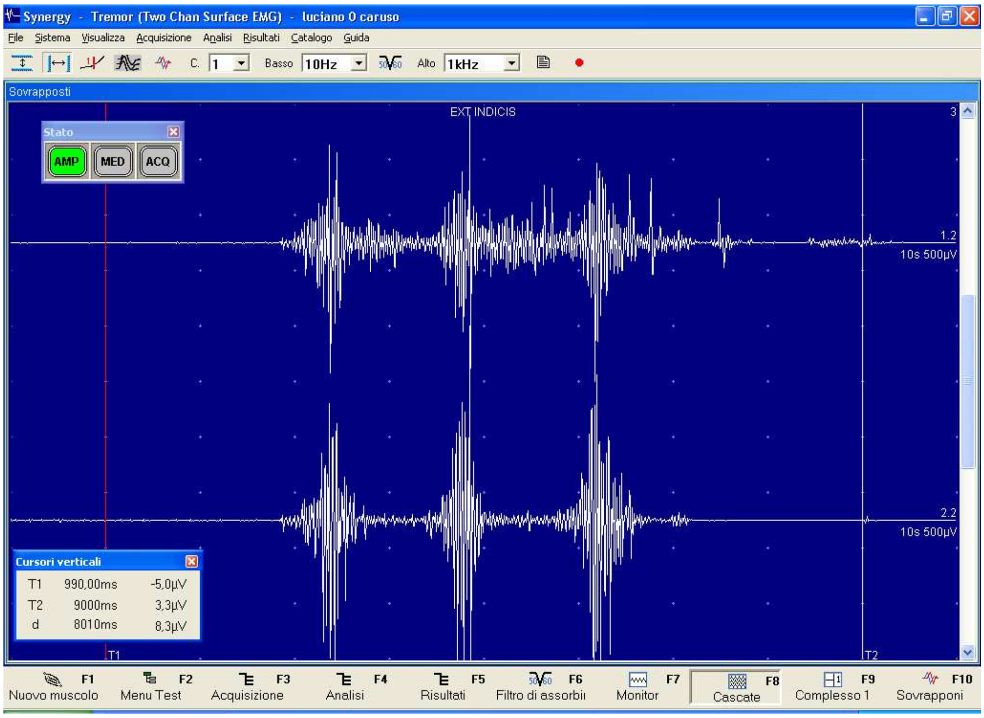

Fig. 2 – Electromyography carried out during a cutting

For each experiment three repetitions were carried out using two different shear and the test was conducted according to a completely randomized scheme, allowing subsequent statistical validation.

Results and discussion

The processing of data collected during the operations conducted in the laboratory, allowed to observe the ability of the clinical test to read and interpret the effort made by the muscles of the arm of the pruner in particular between the two shears tested. It was also developed an analysis of variance in order to statistically show significant influences of the factors considered during the test, on the results of muscular effort pointed out from medical records.

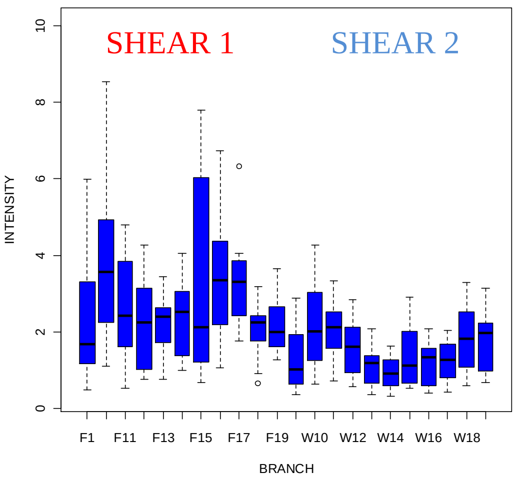

Fig. 3 Intensity in all cuts

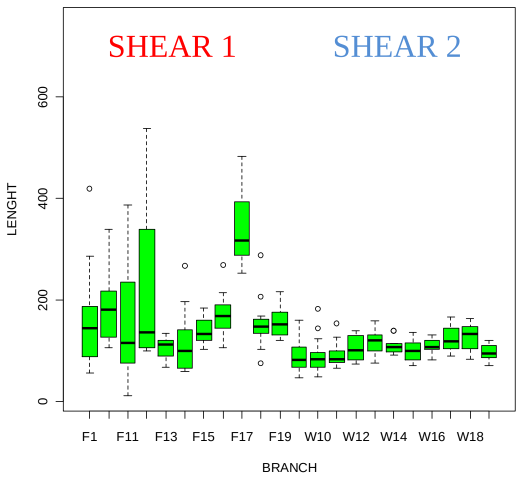

Fig.4 Length in all cuts

The analysis of variance developed over the intensity and duration of the detected peaks during the cuts showed statistical significance for the type of shears used (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 operator influence on the intensity of cut, probably for the influence of anthropometric values. These results 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.

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References

Camillieri, D., Romano, E., Bonsignore, R., Rapisarda, V., Schillaci, G., 2011. Hand Forces Measured During Vine Shoot Cutting. Proceeding of XXXIV CIOSTA CIGR V Conference 2011, 120-121.

Colombini D., Occhipinti E., Fanti M. 2005. Il metodo OCRA per l'analisi e la prevenzione del rischio da movimenti ripetuti. Collana Salute e lavoro, Franco Angeli Editore.

Disselhorst-Klug, C.; Shmitz-Rode, T.; Rau, G. 2009. Surface electromyography and muscle force: Limits in Semg-Force: limits in sEMG-force relationship and new approachesfor applications. Clinical Biomechanics 24, 225-235.

Fransson, C., Winkel, J., 1991. Hand strength: the influence of grip span and grip type. Ergonomics 34 (7), 881–892.

Gurram, R., Rakheja, S., Gouw, G.J., 1995. A study of hand grip pressure distribution and EMG of finger flexor muscles under dynamic loads. Ergonomics 38 (4), 684–699.

Pyykko, I., Farkkila, M., Toivanen, J., Korhonen, O., Hyvarinen, J., 1976. Transmission of vibration in the hand-arm system with special reference to changes in compression force and acceleration. Scandinavian Journal of Environment and Health2, 87–95.

Reidel, S., 1995. Consideration of grip and push forces for the assessment of vibration exposure. Central European Journal of Public Health3, 139–141.

Romano, E., Bonsignore, R., Camillieri, D., Conti, A., Schillaci, G., 2010. Evaluation of Hand Forces During Manual Vine Pruning. Proceeding of International Conference Ragusa SHAWA 2010, 94.

Romano, E., Camillieri, D., Bonsignore, R., Schillaci, G., 2011. Perceived stress and measured forces in vineyard pruning. Proceeding of XXXIV CIOSTA CIGR V Conference 2011, 120-121.

Roquelaure, Y., Gabignon, Y., Gillant, J.C., et al., 2001. Transient hand paresthesias in vineyard workers of Champagne. Am. J. Indust. Med. 40, 639–645.

Roquelaure, Y., Dussolier, G., Dano, C., et al., 2002. Biomechanical strain on the hand–wrist system during grapevine pruning. Int. Arch. Occup. Environ. Health 75, 591–595.

Wakula, J., Beckman, T., Hett, M., et al., 2000. Ergonomic analysis of grapevine pruning and wine harvesting to define work and hand tools design requirements. Occup. Biomechanics 2, 151–161.

Welcome, D., Rakheja, S., Dong, R., Wu, J., Z., Schopper, A., W., 2004. An investigation on the relationship between grip, push and contact forces applied to a tool handle. International Journal of Industrial Ergonomics, 34, 507–518.

ISO/WD 15230, 2000. Definition and guidelines for the measurement of the coupling forces for operators exposed to hand-arm vibration. ISO/TC 108/SC 4/WG 3.