MUSCULOSKELETAL DISORDERS IN AGRICULTURE: FROM IDENTIFYING THE RISKS TO ADOPTING PREVENTIVE MEASURES

Examples of projects financed by INAIL

Introduction

The purpose of this paper is to present experiences of the Istituto Nazionale per l'Assicurazione contro gli Infortuni sul Lavoro (INAIL, Italian National Institute for Insurance against Accidents at Work) both in assessing the biomechanical risk in agriculture and in supporting companies for the adoption of prevention measures.

Agriculture, characterised by many tasks and activities that are not standardised but vary according to daily and seasonal working needs, is one of the working sectors with the highest rates of accidents and of musculoskeletal disorders (MSDs).

Activities depend also on places, environmental conditions, and type of machinery and tools used. Currently, agriculture is characterised by a wide use of machines and technological systems, but many manual activities still involve repetitive movements of upper limbs and manual handling, carrying, pulling and pushing of loads; the assumption and maintenance of awkward or static postures can also affect various joint areas of the body. As a result, biomechanical overload is a significant risk for agricultural workers alongside other risks deriving from physical factors (mainly noise and vibrations, but also working in cold and hot environments), chemical factors (exposure to pesticides, herbicides, etc.) and biological factors.

The management of biomechanical risk represents a great challenge, mainly due to the number of tasks and work cycles, and the heterogeneity of the work methods and times, often organised on a seasonal basis. Agriculture is characterised by limited possibilities of modifying specific work steps; difficulty in finding sufficient economic resources for preventive measures; and lack of adequately trained personnel.

In Italy, the causes of this phenomenon can be attributed not only to the peculiarity of agricultural work, but also to a plurality of factors including agronomic aspects, such as the small extent of crops on any one farm or the orographic characteristics of large areas of the country, and technological aspects related to the obsolescence of parts of agricultural machinery and tractors.

This paper focuses on the following:

- *statistical evidence* of MSDs among agricultural workers;
- *how to evaluate the risk* deriving from biomechanical overload in agriculture; for this purpose, the paper illustrates standardised methods and presents the results of a case study based on an INAIL experimental assessment of MSDs caused by manual work in agriculture in the Marche region;
- *how to improve working conditions* as regards biomechanical overload in agriculture; for this purpose the paper presents some examples of projects financed by INAIL through Incentivi di Sostegno alle Imprese (ISI, enterprise support incentives) to reduce the risk of MSDs in agricultural processing.

Statistical evidence on MSDs in agriculture

Risks from biomechanical overload for agricultural workers are highlighted by the incidence of musculoskeletal diseases such as hernias, arthropathies, shoulder injuries, epicondylitis, synovitis and tenosynovitis and some kinds of nervous system disorders such as carpal tunnel syndrome.

In this section, European and Italian statistical data on MSDs in agriculture are shown.

European data

MSDs can be caused by several occupational and non-occupational factors, frequently occurring simultaneously. In many cases it is difficult to detect the exact cause of a disease. Furthermore, criteria for MSD diagnosis and compensation are not standardised across EU Member States. For these reasons, comparing national data on occupational MSDs is not an easy task.

EU-OSHA has recently published a report that synthesises data and information on MSDs in national reports of 10 Member States, including Italy (EU-OSHA, 2020). Even considering the differences in sources of data (self-reported or administrative data) and in compensation systems, the report confirms, in all Member States investigated:

- the importance of MSDs;
- their impact in terms of both workers' well-being and economic aspects (including direct and indirect costs).

The report highlights that agriculture is among the sectors in which there is a higher prevalence of MSDs, alongside extractive industries, manufacturing, construction and transport.

According to a previous EU-OSHA report (EU-OSHA, 2019a), about three out of every five European workers report MSD complaints, mostly backache and muscular pains in the upper limbs. The results of the sixth wave of the European Working Conditions Survey show that in agriculture 69 % of workers report having suffered back pain in 2015, while 56 % of workers report pain in the upper limbs.

Several factors appear to play an influence on work-related MSDs, namely:

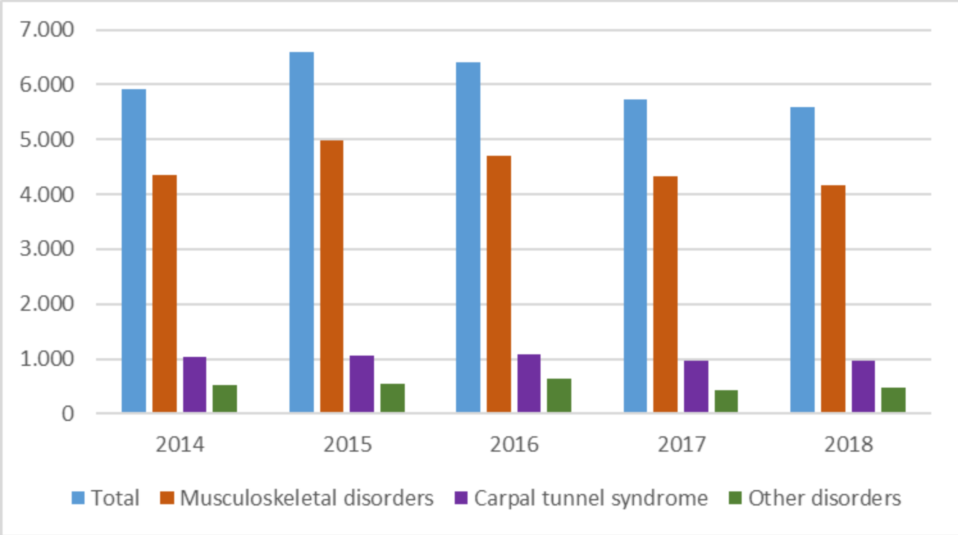
- physical factors (or biomechanical risk factors), including vibrations from manual tools or machinery, machine-paced work, lifting and carrying heavy loads, and so on;
- organisational and psychosocial factors;
- individual and sociodemographic risk factors, such as age and gender, professional status and level of education.

In agriculture, workers report being exposed mainly to risks from postural conditions (tiring and painful positions), carrying or moving heavy loads, working at low temperatures indoors and outdoors, and vibrations from manual tools and machinery (EU-OSHA, 2019a).

Italian data

INAIL data for the period 2014-2018 (INAIL, 2020) show that in agriculture occupational diseases with confirmed professional aetiology consist mainly of MSDs (73-75 % of all cases). In the same period, carpal tunnel syndrome cases accounted for 16-17 % of the total (Figure 1).

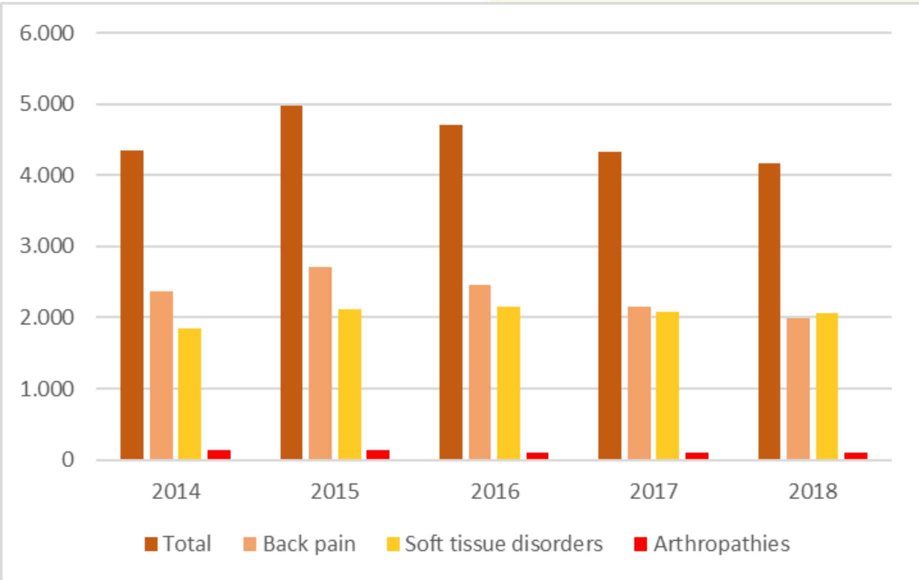
Figure 1: Occupational diseases in agriculture in Italy, confirmed cases 2014-2018



Source: based on INAIL data (INAIL, 2020)

In more detail, Figure 2 shows that MSDs are mainly constituted by back pain caused by hernias and other pathologies of the intervertebral discs, by soft tissue disorders (mainly in the shoulder) and to a lesser extent by arthropathies (mainly in the knee and in the hip).

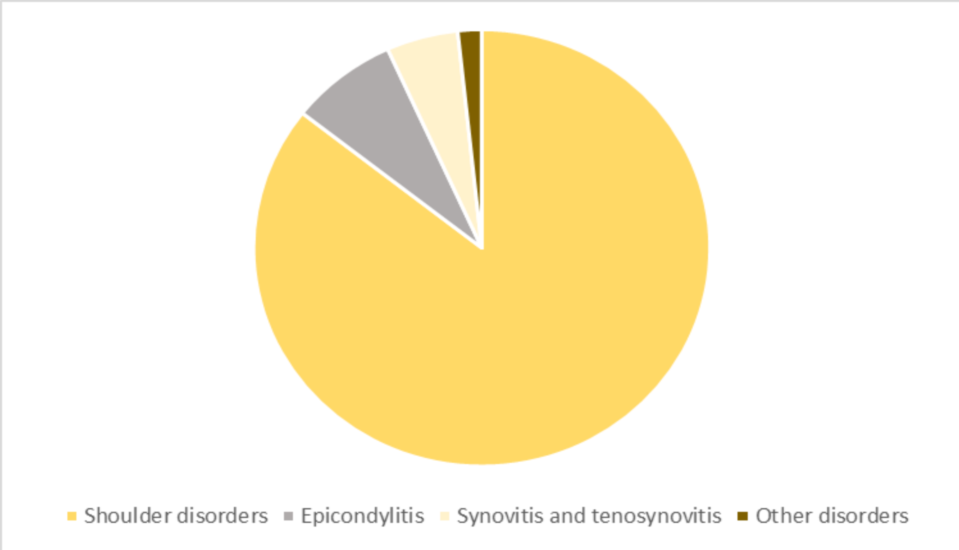
Figure 2: Musculoskeletal disorders in agriculture in Italy, confirmed cases 2014-2018



Source: based on INAIL data (INAIL, 2020)

Most soft tissue disorders (85 % of all cases of this kind) are shoulder pathologies (shoulder injuries, rotator cuff syndrome, etc.); the remaining cases are epicondylitis, synovitis and tenosynovitis and other pathologies (Figure 3).

Figure 3: Soft tissue disorders in agriculture in Italy, confirmed cases 2018



Source: based on INAIL data (INAIL, 2020)

Assessment of biomechanical risk in agriculture

Background

The elimination or reduction of biomechanical risk in agriculture should be achieved by the following steps:

- the detailed collection of data on working tasks;
- the analysis of data and risk assessment by means of standardised methods;
- the identification of the proper measures to eliminate or reduce risks.

However, many reasons make it difficult to carry out a risk assessment in agriculture:

- the working activities are not standardisable;
- the different cultivation tasks vary according to the seasons;
- the environmental conditions vary widely (sunny/rainy and hot/cold periods);
- workers have different personal characteristics (age, gender, height, etc.), often not identifiable a priori because of the use of seasonal workers.

The methods for the assessment of biomechanical risks proposed by the literature and technical standards are not always suitable, since they have been developed for standardised activities, for which frequency of actions, methods and movements can be well defined.

Nevertheless, international technical standards remain the main reference for the evaluation of biomechanical risk in agriculture. Their field of application is defined in detail: for this reason, some studies are being carried out to develop evaluation methods suitable for particularly complex activities, as is the case with agriculture.

In the following paragraphs, some of these standards are indicated for the specific risks that may cause MSDs in agriculture, with reference to the following items:

- handling of low[1] loads at high frequency;
- manual lifting and carrying of loads;
- manual pushing and pulling of loads;
- static postures.

[1] The English version of ISO 11228-3 uses the expression “low loads” where “low” means “light”.

Handling of *low* loads at high frequency

This is one of the major causes of biomechanical overload of the upper limbs. Some examples are:

- pruning;
- fruit thinning;
- fruit and vegetable harvesting.

The risk assessment can follow the guidance of ISO 11228-3 (2007) and ISO/TR 12295 (2014).

These standards propose various methods. The one to be preferred is the Occupational Repetitive Actions (OCRA) index; nevertheless, the OCRA checklist (ISO/TR 12295, 2014), derived from the former, also allows one to calculate a risk index and to correlate it to epidemiological data. These methods take into account different risk factors: frequency of actions, force, posture, repetition (“stereotype”)[2], inadequacy of recovery periods, duration of repetitive tasks and other additional factors. Technical standards allow the assessment of one or more repetitive tasks performed in a single shift; however, algorithms for evaluation of longer periods (weekly, monthly and annual) are being studied to achieve more accurate results for non-standardisable activities, such as agriculture.

Manual lifting and carrying of loads

Manual lifting and carrying of loads can pose risks owing to the weight of objects, the worker’s posture, the duration of the task and the frequency of handling. Some examples of these activities are:

- lifting boxes and carrying them to a trailer;
- lifting and carrying equipment (electric or pneumatic pickers, etc.).

For these operations, the primary references are ISO 11228-1 (2003) and ISO/TR 12295 (2014). They take up, with appropriate modifications and additions, the equation proposed by the National Institute for Occupational Safety and Health (NIOSH), USA, which enables the calculation of a risk index.

Manual pushing and pulling of loads

Manual pushing and pulling of loads and objects can be risky because of the distance travelled, the characteristics of the working environment, the posture, and the frequency and extent of application of force.

In agriculture, this type of action is less frequent than manual lifting and carrying of loads but still needs to be considered and occurs, for example, in the storage of crop products, plant protection products, machinery, etc.

For these actions, the risk assessment follows the guidelines of ISO 11228-2 (2007), which enables the calculation of a risk index.

Static postures

Many manual agricultural activities involve maintaining static working postures, which, according to ISO 11226 (2000), can be defined as working postures maintained for longer than 4 seconds with slight or non-existent variations around a fixed force level.

Some examples are:

- pruning, picking grapes and other fruit, etc. which involve postures with raised arms;
- picking tomatoes and other vegetables (postures with bent back);
- strawberry harvesting, which needs kneeling and crouching postures.

For operations implying the assumption of static postures, the risk assessment can be conducted in accordance with ISO 11226 (2000); this does not allow one to calculate a risk index but only enables one to define whether a posture is acceptable or not.

[2] “Stereotype” is a technical term used by ISO/TR 12295, meaning “repetition”.

The field of application of the technical standards is very precisely defined: for this reason, some studies are being carried out to develop evaluation methods suitable for particularly complex activities, such as agriculture.

Obsolete machinery

Using obsolete machinery can be another factor influencing MSDs for agricultural workers, as it involves greater use of manual processes, non-ergonomic workstation and higher level of whole-body vibrations that are increased by the movement of tractors and machines on an uneven ground.

Vibrations are a relevant factor affecting MSDs, because they can be the cause of hernias and other dorsopathies.

Since the end of the 1950s, the number of tractors in Italy has increased by about 8 times, from 240,000 units to about 2,000,000 today (Mancini & Laurendi, 2017), with a significant increase also in the average engine power, which went from 35 horsepower in the 1960s to over 98 horsepower in 2014 (Bartolozzi, 2016).

Italy has thus become one of the main European tractor markets (CEMA, 2020), but, owing to the difficulty for small farms to update their fleet, in 2016 only 11 % of tractors were under 10 years of age while more than 50 % of them were over 24 years old (Unione nazionale contoterzisti agromeccanici e industriali, 2019).

Moreover, in Italy, as well as in Spain and Greece, because of the orographic situation, tracked tractors are relatively widespread, since they guarantee stability and better performance on rough and uneven terrain; on the other hand, they may be associated with a higher risk of contracting MSDs.

These conditions, if combined with limited maintenance, expose workers not only to impacts, but also to shaking and whole-body vibrations that can exceed the daily action value ($A8 = 0.5\ m/s^2$), to prolonged sitting in forced and incorrect postures, and to frequent spine twisting and positions with the head turned.

Both whole-body vibrations and awkward postures can cause back pain, hernias and other pathologies of the intervertebral discs.

The occurrence of such disorders also depends on the workload and on individual and environmental factors, such as anthropometric characteristics of the worker, muscle tone and susceptibility (age, pre-existing disorders, gender, etc.). However, a significant reduction in risk could be achieved through the renewal of machinery or targeted interventions, such as the replacement of seats with others equipped with modern devices to improve comfort (hydraulic or pneumatic suspension).

Case study: evaluation of the risk of biomechanical overload of the upper limbs in the Marche region (Italy)

Introduction

The agricultural sector in the Marche region, in central Italy, can be considered representative of the farming procedures carried out in the hilly areas of the entire national territory. The agricultural sector in the Marche region is characterised by small and very small farms, mainly family-run with at most the collaboration of seasonal workers. Farms sometimes spread over a few hectares in the plains but are mostly in the hilly areas, and mainly dedicated to arable crops (wheat, sunflower, rapeseed, maize, etc.), vineyards, olive tree and orchards (plums, apricots, peaches, cherries, etc.).

The arable land is farmed exclusively with the use of mechanical means, such as agricultural tractors, combined harvesters, etc. On the other hand, the other crops above mentioned are characterised by a high number of manual tasks, which also imply the use of electro-pneumatic (pneumatic shears, olive harvesters, etc.) and manual tools (scissors, hacksaws, etc.).

INAIL has collaborated with the Polytechnic University of Marche of Ancona and the University Didactic-Experimental Agricultural Company P. Rosati. The latter is active in farming herbaceous and arboreal species typical of central Italy. A 2-year study was completed in order to estimate the risk of biomechanical overload of the upper limbs, in different seasonal work phases, typical of the cultivation of vineyards, olive trees and orchards, as well as strawberries.

The findings of this extensive study on the assessment of biomechanical risk and its level (from low to high) for upper limbs in working with four type of crops are presented below. The four types of farming examined in the study are viticulture, olive growing, orchards (fruit growing) and strawberry cultivation.

The evaluation method used was the OCRA checklist, as indicated by the most recent technical standards (ISO 11228-3 and ISO/TR 12295). It has the merit of taking into consideration all the risk factors involved in biomechanical overload (frequency of action, application of strength, assumption of awkward postures, additional factors, occurrence and distribution of breaks, and duration of daily work).

The assessment was made for the entire working day of 8 hours, with two breaks of 10 minutes each, in addition to the midday break. The risk for the right and left upper limbs was assessed separately and expressed as percentage of measurements characterized by different risk levels.

For each type, the results of the study are summarised with regard to:

- frequency of actions (in this case study ranging from low-moderate to high);
- application of force (in this case study ranging from low-moderate to significant);
- time of assumption of awkward positions (in this case study ranging from significant through extended to extreme).

Viticulture

The vineyards were located on a steep slope and arranged in parallel rows, with a height of 2 m and spaced 5-6 m apart. The phases of dry and green pruning, suckering and harvesting, with the use of manual and electric or pneumatic shears, were evaluated.

Viticulture (Photos 1 and 2) is characterised by:

- low-moderate frequency of actions in the manual adjustment of the vine shoots and winter pruning phase with manual shears (both upper limbs);
- application of force highlighted in harvesting (both upper limbs);
- assumption of awkward postures for significant periods, in the articular districts of the shoulders as a result of the harvesting and arrangement of the vine shoots, as well as in the joint districts of the elbows in arranging the shoots; maintaining both hands in “pinch” posture, for significant periods, in the harvesting and setting up of the shoots.

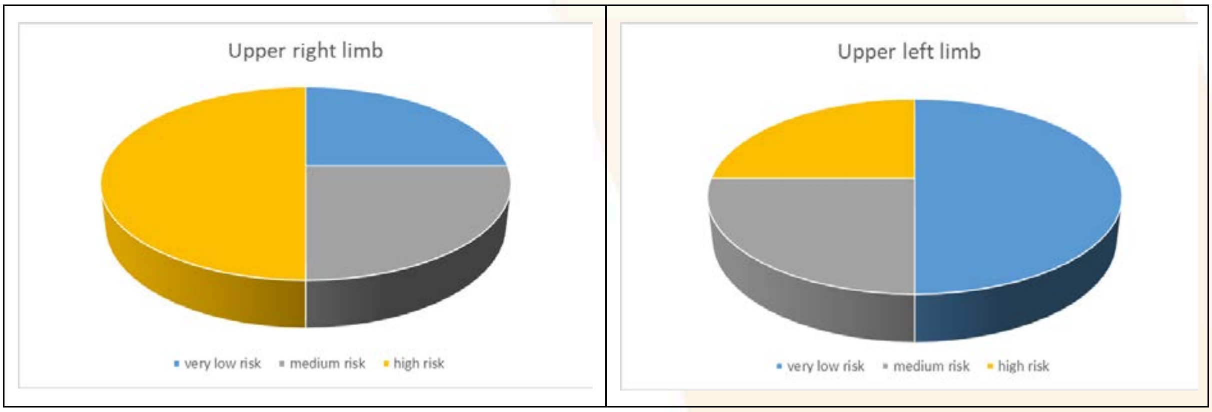
Photo 1: Pruning with manual scissors

Source: photo by Ugo Caselli

Photo 2: Manual grape harvesting

Source: photo by Ugo Caselli

Figure 4: Risk from biomechanical overload of the upper limbs assessed with the OCRA checklist in viticulture (as percentage of measurements)



Source: based on data collected by INAIL in the case study

Olive growing

The olive trees of the Leccino and Frantoio varieties, about 35 years of age, were arranged on a steep slope, kept at a height of no more than 4-5 m, in parallel rows spaced 5-6 m apart. The manual pruning and olive-harvesting phases, with the use of olive pickers and electric or pneumatic shears, were evaluated.

In olive growing (Pictures 3 and 4), the following has been estimated:

- low-moderate frequency of actions in the pruning phase with the use of electric shears (dominant upper limb) and harvesting with the use of electric facilitator (both upper limbs); significant frequency of actions in the manual olive-harvesting phase with the use of a rake;
- application of significant force in olive harvesting with electric facilitator, with both upper limbs;
- awkward postures of both shoulders, for extended times, in the pruning phase with the use of electric shears, collection with electric facilitator and manual collection with rake; flex-extensions, for low-moderate times, of the elbows in the same phases mentioned above; awkward "grip" posture for most of the working time, with both hands, in the manual harvesting phase with rake.

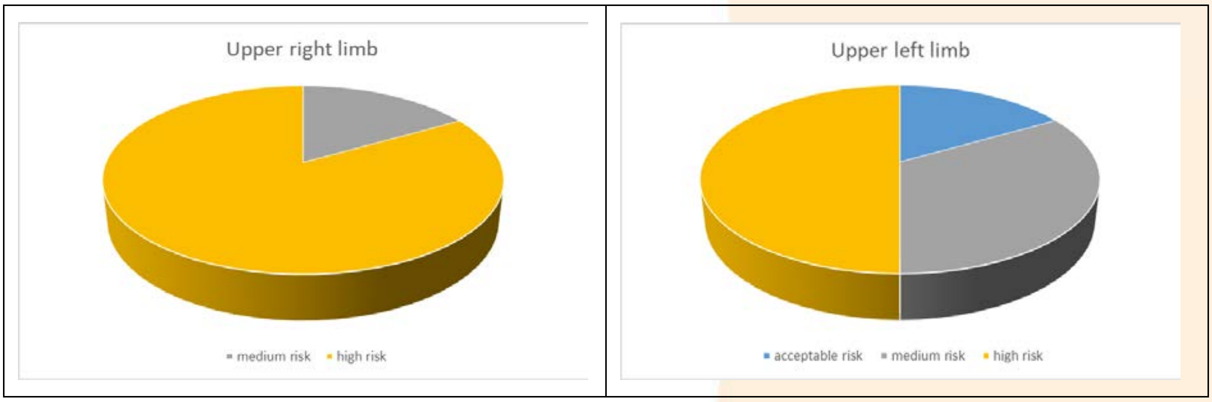
Photo 3: Manual pruning

Source: photo by Ugo Caselli

Photo 4: Olive collection with electric facilitator

Source: photo by Ugo Caselli

Figure 5: Risk from biomechanical overload of the upper limbs assessed with the OCRA checklist, in olive growing (as percentage of measurements)



Source: based on data collected by INAIL in the case study

Orchards (peaches, apricots, cherries, plums and apples)

The fruit trees, arranged on steep slopes, were kept at a height of about 2-3 m, in parallel rows spaced about 5-6 m apart. Working operations on the plants are carried out from the ground. The pruning, thinning and harvesting phases, with the use of hacksaws, manual and electro-pneumatic shears, were analysed.

Fruit growing (Pictures 5 and 6) is characterised by:

- high frequency of actions especially with the dominant upper limb, in the fruit-harvesting phases and also thinning;
- application of significant force (with both upper limbs) in the pruning phases with the use of manual tools, such as hacksaws, shears and scissors;
- assumption of awkward postures for times that can be extreme, related to the shoulders of both upper limbs, in the manual pruning, thinning and fruit-harvesting phases; the joints of the elbows and wrists can also be significantly involved in these phases and, during the collection phase, the hand of the dominant limb assumes mainly a posture in “pinch”.

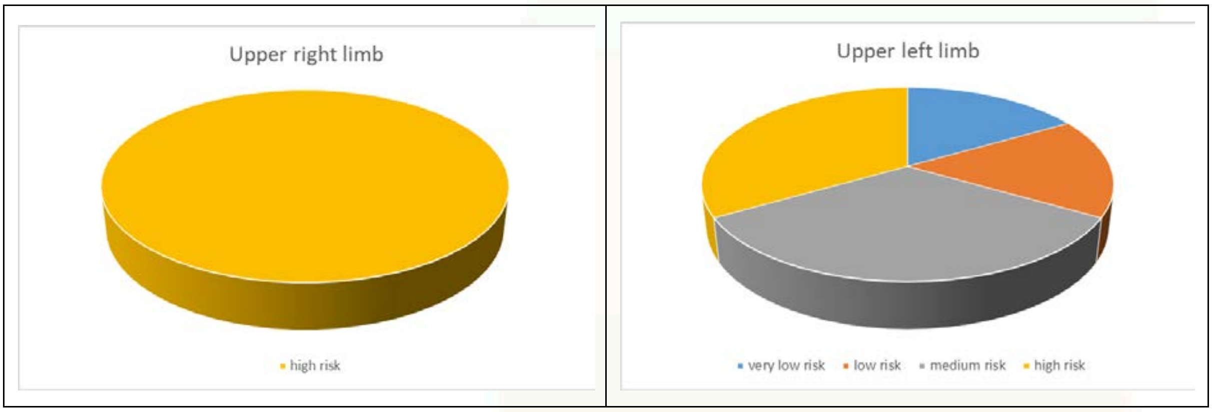
Photo 5: Manual pruning

Source: photo by Ugo Caselli

Photo 6: Manual cherry harvesting

Source: photo by Ugo Caselli

Figure 6: Risk from biomechanical overload of the upper limbs assessed with the OCRA checklist, in fruit growing (as percentage of measurements)



Source: based on data collected by INAIL in the case study

Strawberry cultivation

Different varieties of strawberry grow on the ground, on a flat surface, in parallel rows spaced about 1 m apart. The manual phases of planting, stolon storage and harvesting were analysed.

Strawberry cultivation (Pictures 7 and 8) involves:

- low-moderate frequency of actions, beginning with the manual winter cleaning of the plants, but also in the collection of strawberries and planting of the seedlings;
- moderate application of force with both upper limbs during the winter cleaning of the plants;
- awkward grips in both hands, in all the work phases envisaged; the wrist of the dominant limb is also involved in awkward postures.

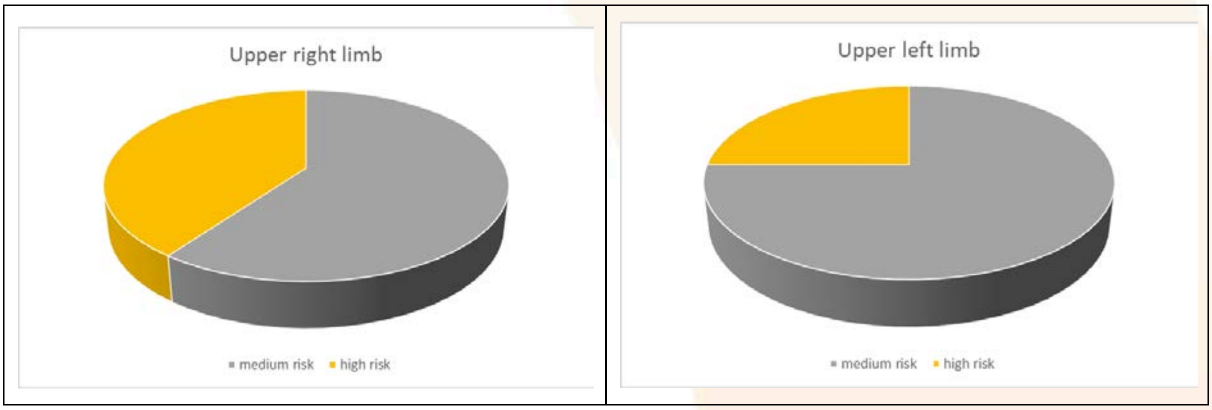
Photo 7: Phase of planting

Source: photo by Ugo Caselli

Photo 8: Manual strawberry harvesting

Source: photo by Ugo Caselli

Figure 7: Risk from biomechanical overload of the upper limbs assessed with the OCRA checklist, in strawberry cultivation (as percentage of measurements)



Source: based on data collected by INAIL in the case study

Results

This study estimated:

- dynamic frequency of actions, generally in the ranges of 40-50 and 60-70 actions per minute (higher values in the thinning and harvesting of fruit);
- application of low-moderate force (in particular in the manual harvesting and in the harvesting with manual olive picker);
- assuming awkward postures, even extreme ones, specifically with the shoulder joint districts (keeping the arms level with or above the shoulders) and hands (in a "pinch" posture at times for most of the work), particularly following the pruning, thinning and harvesting of grapes, olives and fruit.

Based upon these findings, it is possible to emphasise how these crops are responsible for exposing workers to the risk of biomechanical overload of the upper limbs, up to medium and high levels, depending on the individual work phases. However, these estimates refer to a single working day, since the evaluation methods proposed by the technical literature and the most recent standards, including the OCRA checklist, do not make it possible to assess risk on a seasonal or annual basis, as would be desirable for the agricultural sector. Certainly, an agricultural worker is assigned to different work phases during the year, each of which generally lasts for one or more working days; this may lead to an increased risk of MSDs in the upper limbs and their joints.

Programmes to support companies to prevent MSDs in agriculture

The INAIL ISI incentive schemes

In Italy, INAIL supports worker protection through an integrated system that includes medical and financial assistance for victims of workplace accidents or occupational diseases, as well as rehabilitation and reintegration to social life and work.

At the same time, INAIL supports enterprises by means of information, training, assistance and advice concerning health and safety at the workplace.

Furthermore, INAIL provides financial support for the implementation of projects aimed at improving health and safety at workplace through the ISI programme concerning the realisation of innovative technological and organisational solutions (EU-OSHA, 2019b).

The ISI scheme is funded by INAIL's internal resources derived from companies' compulsory insurance premiums. The ISI scheme has been applied every year since 2010. It provides non-repayable grants up to 65 % of the project cost, to a maximum of €50,000 to €130,000, depending on the project/intervention category (INAIL, 2018).

Starting from 2016, INAIL has activated a particular type of financing instrument for micro and small farms linked to the primary agricultural production (INAIL, 2016). This agricultural funding scheme follows specific rules in accordance with Commission Regulation (EU) No 702/2014. The main characteristics of the scheme are:

- non-repayable grants are up to 40 % of the project cost (50 % for young farmers) to a maximum of €60,000;
- the funding must be for the purchase of agricultural machines or tractors.

For every machine or tractor requested, the farm has to demonstrate improvement regarding these requirements:

1. enhancement measures in terms of one of the following items:
    - improvement of the overall performance and sustainability,
    - reduction of airborne emissions;
2. reduction of occupational risks related to one of the following factors:
    - use of obsolete machines and tractors,
    - noise,
    - manual work.

As regards manual work, several pieces of evidence support the a priori demonstration of workers' health improvement through the mechanisation of agricultural manual operations, since mechanisation reduces awkward postures, for example those with raised arms, lifting and carrying of loads, and handling of low loads at high frequency. However, mechanisation should take account of ergonomic principles to make sure it does not introduce new risks for workers.

Examples of relevant projects

By means of the ISI agricultural scheme of 2016, INAIL funded about 1,000 projects, 70 of which included the purchase of agricultural machines intended for the mechanisation of manual operations and therefore to prevent overload on workers and avoid MSDs. Many of these machines are fruit and vegetable harvesters, for example:

- orchard platforms;
- grape-harvesting machines, either motorised or towed;
- olive shakers and harvesting machines;
- vegetable harvesters.

Biomechanical risks can be reduced in several ways by the use of these machines.

For example, orchard and pruning platforms help workers keep a proper posture, avoiding static and protracted positions with raised arms. Conversely, vegetable harvesters avoid staying in bent down positions. Grape- and olive-harvesting machines, besides avoiding awkward postures, reduce the occurrence of risks related to high-frequency movements.

Some examples of the effects of agricultural machines on factors influencing biomechanical risk are shown in the following tables.

Example 1: Olive harvesters

In olive harvesting, mechanisation can concern the entire process, that is, detaching and catching olives, or only part of it. Furthermore, mechanisation can be partial or total in terms of residual manual work in each phase. In particular, machineries include mechanical harvesting aids that are hand carried by the worker, such as vibrating combs or small shakers, and machines towed by tractor or motorised, such as trunk shakers or the more complex over-the-row harvesters (International Olive Council, 2007).

The choice among the different options depends not only on economic aspects but also on the characteristics of the terrain and of the orchard and trees. In the example shown in Table 1, harvesting by means of hand-carried mechanical aids for detaching olives is compared with harvesting by means of a trunk shaker with wrap-around catching frame.

Table 1: Impacts of mechanisation on biomechanical risk in olive growing

<table>
<tr><td colspan="2">Olive tree shaker and harvester</td><td>
Source: drawing by Riccardo Vallerga</td></tr>
<tr><td colspan="3">Operations</td></tr>
<tr><td colspan="2">Harvesting by means of hand-carried mechanical aids for detaching olives, and manual catching</td><td>Mechanical harvesting and catching by means of self-propelled trunk shaker with wrap-around catching frame</td></tr>
<tr><td colspan="2">Manual combs or mechanical harvesting aids such as hand-held vibrating combs or electric or pneumatic beaters and shakers make olives fall on the nets lying on the ground</td><td>The shaker moves forward, secures the trunk with clamps and opens the catching frame, a kind of upside-down umbrella wrapped around the tree. The shaking of the trunk causes the olives to fall on the catching frame and from there into a bin (which holds 150-200 kg)</td></tr>
<tr><td colspan="2">The nets are moved and the crates filled (23-25 kg each) manually</td><td rowspan="2">The bin is lifted and the olives are loaded directly into a larger bin or in the trailer</td></tr>
<tr><td colspan="2">The crates are carried to the trailer</td></tr>
<tr><td>Risk factor</td><td>Increase</td><td>Reduction</td></tr>
<tr><td colspan="3">Manual handling</td></tr>
<tr><td>Lifting and carrying</td><td></td><td>with regard to crates</td></tr>
<tr><td>Handling of low loads at high frequency</td><td></td><td>with regard to rakes</td></tr>
</table>

Postures		
Body twist		with regard to handling manual or vibrating rakes
Long-lasting static postures with raised arms		with regard to handling vibrating rakes during harvesting from tall trees
Bent down postures		with regard to moving plastic tarpaulins and filling the crates
Hand posture: pinch		with regard to handling manual rakes
Hand posture: grip		with regard to handling vibrating rakes
Vibrations		
Hand-arm vibrations		with regard to electric/pneumatic harvester tools
Whole-body vibrations	with regard to driving and using tree shakers	

As outlined in Table 1, the use of trunk shakers significantly reduces or even eliminates the main musculoskeletal risks arising from manual harvesting. In particular, the risks due to keeping the upper limbs in a raised position and to the vibrating combs or shakers in the canopy are eliminated. Moreover, by using olive trunk shakers, workers are not exposed to the hand-arm vibrations induced by electrical or pneumatic hand-carried combs or shakers.

The biomechanical risk deriving from manually laying and moving the nets and from filling and carrying the crates is also eliminated.

Example 2: Grape harvesters

A particularly interesting intervention from the point of view of the prevention of MSDs is the purchase of harvesting machines that allow the mechanisation of most manual vineyard cultivation operations.

Viticulture in Europe represents almost 60 % of the world's viticulture (44 % in Spain, France and Italy alone) and over 65 % of the world's wine production, and is practised in 17 countries of the European Union (*Corriere Vinicolo*, 2020).

The use of grape-harvesting machines is greater in France and Germany, but in recent years it has also assumed substantial proportions in Spain and Italy. In Italy, mechanisation had been limited in the past by the small average surface area of farms, the location of many vineyards on steeply sloping terrain and the considerable spread of forms of cultivation not suitable for mechanisation (e.g. short inter-row distances).

A very common type of grape harvester has a sort of tunnel with a suspended free-swinging harvesting head. Two sets of parallel bars for shaking the vegetation are mounted on the harvesting head. The grapes detached from the stalks fall on catcher trays and are conveyed to a sorter that ensures removal of foreign bodies, and finally to the loading tank.

Harvesting machines can also mount tools suitable for all cultivation operations and make it possible to greatly reduce the risks arising from awkward postures, repetitive movements, and manual lifting and carrying (e.g. grape boxes during harvesting).

Table 2: Impacts of mechanisation on biomechanical risk in grape harvesting

<table>
<tr><td colspan="2">Grape harvester</td><td colspan="2">
Source: drawing by Riccardo Vallerga</td></tr>
<tr><td colspan="4">In technical e Operations</td></tr>
<tr><td colspan="2">Manual harvesting</td><td colspan="2">Mechanical harvesting by means of an harvesting head mounted on an over-row straddle tractor</td></tr>
<tr><td colspan="2">Harvesting uses manual, electric or pneumatic scissors</td><td colspan="2">The harvesting head enters the row and is automatically aligned; the harvesting head removes grapes, separates berries and juice, and brings them into a big bin (2,000-5.000 l)</td></tr>
<tr><td colspan="2">The crates (23-25 kg each) are filled manually</td><td colspan="2" rowspan="2">The bin is lifted and the berries and juice are loaded in the trailer</td></tr>
<tr><td colspan="2">The crates are carried to the trailer</td></tr>
<tr><td>Risk factor</td><td colspan="2">Increase</td><td>Reduction</td></tr>
<tr><td colspan="4">Manual handling</td></tr>
<tr><td>Lifting and carrying</td><td colspan="2"></td><td>with regard to crates</td></tr>
<tr><td>Handling of low loads at high frequency</td><td colspan="2"></td><td>with regard to bunches</td></tr>
<tr><td colspan="4">Postures</td></tr>
<tr><td>Body twist</td><td colspan="2"></td><td>with regard to filling the crates with bunches</td></tr>
<tr><td>Awkward postures of the shoulders</td><td colspan="2"></td><td>with regard to the cutting of the bunches</td></tr>
<tr><td>Hand posture: pinch</td><td colspan="2"></td><td>with regard to the cutting of the bunches</td></tr>
<tr><td>Hand posture: grip</td><td colspan="2"></td><td>with regard to electric or pneumatic scissors</td></tr>
<tr><td colspan="4">Vibrations</td></tr>
<tr><td>Whole-body vibrations</td><td colspan="2">with regard to driving and using straddle tractor</td><td></td></tr>
</table>

As outlined in Table 2, self-propelled or tractor-mounted grape harvesters eliminate the main musculoskeletal risks arising from manual harvesting. In particular, the repetitive movements of cutting the bunches and twisting the body for their insertion in the boxes, and the “pinch” and “grip” hand postures, are eliminated. The reduction of risks is even greater with modern grape harvesters equipped with tools for all cultivation operations.

The added risk of whole-body vibration due to the use of the tractor is negligible because of the high comfort of modern drivers’ seats.

Example 3: Orchard platforms

Fruit harvesting is an operation that involves reaching the branches by means of ladders, picking the fruits while keeping the upper limbs in a raised position, filling the baskets secured to the shoulders with straps and emptying them into the bins on a trailer. Several types of machinery help in performing such operations in order to increase productivity and in the same time reduce the manual effort.

Orchard platforms are widely used in Italian apple orchards as well as in other similar orchards in rows. These machines are not new but they are constantly evolving to offer more functions to the farmers. Platforms can be towed by the tractor or motorised, even electrically; they can also be used for other work such as pruning and thinning. Self-levelling systems make platforms suitable for different types of terrain.

In Table 3 the manual process is compared with using an orchard platform that allows the workers to stay at the canopy height. The platform is equipped with conveyor belts that carry the fruits picked by the workers to the bins placed directly on the back of the platform.

Table 3: Impacts of mechanisation on biomechanical risk in fruit growing

<table>
<tr><td colspan="2">Orchard platform</td><td>
Source: drawing by Riccardo Vallerga</td></tr>
<tr><td colspan="3">Operations</td></tr>
<tr><td colspan="2">Manual harvesting</td><td>Mechanical harvesting by means of an orchard platform</td></tr>
<tr><td colspan="2">The fruits are manually picked and placed in a basket secured to the shoulders (5-10 kg each)</td><td>The orchard platform enters beneath the rows; the workers place the conveyor belts in the most convenient position to put the fruits there</td></tr>
<tr><td colspan="2">The basket is emptied by hand into a bin</td><td>The conveyor belts fill a bin on the back of a platform; when the bin is full the platform loads another empty one</td></tr>
<tr><td>Risk factor</td><td>Increase</td><td>Reduction</td></tr>
<tr><td colspan="3">Manual handling</td></tr>
<tr><td>Lifting and carrying</td><td></td><td>with regard to carrying the baskets</td></tr>
<tr><td>Handling of low loads at high frequency</td><td>with regard to placing the fruit on conveyor belts</td><td>with regard to filling baskets</td></tr>
<tr><td colspan="3">Postures</td></tr>
<tr><td>Long-lasting static postures with raised arms</td><td></td><td>with regard to harvesting from the highest branches</td></tr>
<tr><td>Bent down postures</td><td></td><td>with regard to emptying baskets into bins</td></tr>
<tr><td>Hand posture: grip</td><td>with regard to detaching the fruits</td><td></td></tr>
</table>

As shown in Table 3, the use of orchard platforms considerably reduces the risks to the spine resulting from the filling, transport and emptying of baskets. Nevertheless, the increase in productivity causes a corresponding increase in the frequency of harvesting movements and therefore the persistence of risks due to repetitive movements of the upper limbs, such as those due to detaching the fruits (hand in “grip” posture accompanied by rapid twisting of the wrist) and placing them on conveyor belts.

Conclusions

Agriculture is characterised by working conditions that expose workers to biomechanical risk, as shown by the data on MSDs presented in this paper.

Many of the factors determining the biomechanical risk are difficult to deal with, as they depend on the non-standardisable tasks performed by the worker.

This paper points out the importance of assessing the biomechanical risk factors in the work phases typical of a region or a country, in the conditions in which they are performed.

The adoption of a common methodology by Member States could be the first step to compare similar situations and share experiences on effective solutions. Such a shared approach can provide a tool for policy-makers in choosing strategies for biomechanical risk mitigation.

In general, it is necessary to address this issue from different points of view:

- suggest the use of dedicated manual tools and equipment appropriately designed from an ergonomic point of view, easy to handle and characterised by negligible levels of weight and vibrations;
- support farmers, as feasible, in the purchase, and renewal, of machinery that can facilitate or carry out the operations that have the greatest impact on workers;
- intervene on the basis of factors such as the characteristics of the land worked and the crops grown (varieties, methods of planting, pruning, etc.), as well as the organisation of the work (daily working times, breaks and moments of recovery, etc.).

Mechanisation is particularly important when growing techniques are still based mainly on manual work, as in the cultivation of olives, grapes, other fruit and vegetables.

With a view to devising and implementing prevention and protection measures that can mitigate the risk of biomechanical overload of the upper limbs, it is worth mentioning the possibility of using electro-pneumatic tools to replace manual ones. Although this can reduce some critical issues (application of force and assumption/maintenance of awkward postures), it can, however, cause exposure to other risks, such as hand-arm vibrations.

Self-propelled or trailed machines, such as harvesters or orchard platforms, can greatly reduce the biomechanical risk, but on the other hand can introduce new risks such as those deriving from noise and vibrations, or those due to impacts from mechanical parts, falls from height, or rollover of tractors or machines. However, it is important to emphasise that, as with any change in working conditions, a careful risk assessment must be carried out to ensure the correct use of the machinery in safe conditions.

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References

Bartolozzi F., 2016, ‘Quanto è aumentata la Potenza media dei trattori?’, *Il Contoterzista*, No 2, pp. 76-79.

CEMA - European Agricultural Machinery Association, Market Data 2019, Press release, Brussels, 09 March 2020, https://www.cema-agri.org/index.php?option=com_content&view=article&id=622&catid=32&Itemid=209

Corriere Vinicolo, 2020, No 1, January, pp. 4-6. Available in Italian at: https://corrierevinicolo.unioneitalianavini.it/vino-in-cifre/

EU-OSHA – European Agency for Safety and Health at Work, 2019a, *Work-related musculoskeletal disorders: Prevalence, costs and demographics in the EU*. Available at: https://osha.europa.eu/it/publications/msds-facts-and-figures-overview-prevalence-costs-and-demographics-msds-europe/view

EU-OSHA – European Agency for Safety and Health at Work, 2019b, *INAIL economic incentive programme (Italy)*. Available at: https://healthy-workplaces.eu/it/tools-and-publications/practical-tools/italy-inail-economic-incentive-programme

EU-OSHA – European Agency for Safety and Health at Work, 2020, *Work-related musculoskeletal disorders – Facts and figures*. Available at: https://osha.europa.eu/en/publications/work-related-musculoskeletal-disorders-facts-and-figures-synthesis-report-10-eu-member/view

INAIL, 2016, *ISI Agricoltura 2016* call for projects. Available in Italian at: https://www.inail.it/cs/internet/attivita/prevenzione-e-sicurezza/agevolazioni-e-finanziamenti/incentivi-alle-imprese/bando-isi-agricoltura-2016.html

INAIL, 2018, *ISI 2018* call for projects. Available in Italian at: https://www.inail.it/cs/internet/attivita/prevenzione-e-sicurezza/agevolazioni-e-finanziamenti/incentivi-alle-imprese/bando-isi-2018.html

INAIL, 2020, Statistical Database. Available at: https://bancadaticsa.inail.it/bancadaticsa/bancastatistica.asp?cod=2

International Olive Council, 2007, *Production techniques in olive growing*. Available at: https://www.internationaloliveoil.org/wp-content/uploads/2019/12/Olivicultura_eng-1.pdf

ISO 11226, 2000, *Evaluation of static working postures*. Available at: https://www.iso.org/standard/25573.html

ISO 11228-1, 2003, *Ergonomics – Manual handling – Part 1: Lifting and carrying*. Available at: https://www.iso.org/standard/26520.html

ISO 11228-2, 2007, *Ergonomics – Manual handling – Part 2: Pushing and pulling*. Available at: https://www.iso.org/standard/26521.html

ISO 11228-3, 2007, *Ergonomics – Manual handling – Part 3: Handling of low loads at high frequency*. Available at: https://www.iso.org/standard/26522.html

ISO/TR 12295, 2014, *Ergonomics – Application document for International Standards on manual handling (ISO 11228–1, ISO 11228–2 and ISO 11228–3) and evaluation of static working postures (ISO 11226)*. Available at: https://www.iso.org/standard/51309.html

Mancini G., Laurendi V., 2017, ‘Le macchine quale agente materiale di infortunio in agricoltura’, in: *Agricoltura: salute e sicurezza sul lavoro a 100 anni dall’introduzione della tutela assicurativa*, INAIL. Available in Italian at: https://www.inail.it/cs/internet/comunicazione/pubblicazioni/catalogo-generale/pubbl-agricoltura-salute-e-sicurezza-sul-lavoro-a-100-anni.html

Unione nazionale contoterzisti agromeccanici e industriali, 2019, ‘Un mercato di trattori… abusati’, press office, 28 January. Available in Italian at: https://blog.contoterzisti.it/un-mercato-di-trattori-abusati/