Lecture Notes in Civil Engineering 252

Marcello Biocca · Eugenio Cavallo ·
Massimo Cecchini · Sabina Failla ·
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Safety, Health and Welfare in Agriculture and Agro-food Systems

Ragusa SHWA 2021

Springer

Lecture Notes in Civil Engineering

Volume 252

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ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-3-030-98091-7 ISBN 978-3-030-98092-4 (eBook)
https://doi.org/10.1007/978-3-030-98092-4

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Dear Colleagues and dear Friends,

The 6th edition of Ragusa SHWA, the International Conference devoted to the Safety, Health and Welfare in Agriculture and Agro-food systems, was held during September 15–16, 2021.

The previous editions of Ragusa SHWA took place in September 2008, 2010 and 2012 in Ragusa, Italy. The 4th SWHA edition was held in 2015 in Lodi, Italy, together with the International Congress on Rural Health (ICRH). The two International Conferences adopted together the Lodi Declaration on Rural Health.

Due to the Covid-19 pandemic, Ragusa SHWA 2020 and Ragusa SHWA 2021 were celebrated online, with prestigious scientists reporting their studies highly topical issues.

The Ragusa SHWA conferences have two distinctive characteristics. First, it is celebrated in the same place and shows a high return rate of the participants. Those who participate in one edition are likely to return to the following. This means that the opportunities offered by the location are regarded as authentic strengths. In particular, Sicily and its southeastern part are a real laboratory for actions related to agriculture, agro-food and well-living, in urban, coastal and rural spaces. All factors that promote conviviality, well-being and ultimately the formation of pleasant, profitable and long-lasting partnerships among scientists are present. Moreover, Southeast Sicily, with its lovely and attractive countryside, wonderful beaches, gorgeous Late Baroque UNESCO sites, is a great location fitted for fruitful scientific meetings.

The Ragusa SHWA conferences took place under the aegis of the Presidency of the Italian Republic and were supported by International Commission of Agricultural and Biosystems Engineering (CIGR), Italian Society of Agricultural Engineering (AIIA) and the Department of Agriculture, Food and Environment of the University of Catania, Italy.

During the 2021 6th Ragusa SHWA, 2 Lectio Magistralis, 4 main communications, 25 oral and 40 poster contributions were presented online by more than 240 authors.

The conference has hosted a special session on “Innovation for Smart Dairy Farming” (CowBhave project, PRIN 2017 project), meeting Chair Prof. Claudia Arcidiacono (University of Catania, Italy) and session Chair Prof. Daniele Torreggiani (University of Bologna, Italy) with two lectures on “Innovation and sustainability for smart dairy farming COWBHAVE final results” and eight oral contributions.

The number and the quality of the contributions confirm that Ragusa SHWA conference has once again achieved its three main objectives: updating, contamination and promotion of interdisciplinary research on safety, health and welfare.

This volume collects the 52 reviewed contributions presented at the conference.

Ragusa SHWA loves contamination, collaboration and sharing dreams and doubts with the aim to make results from research actual solutions able to improve life for people and environment.

Our studies are faced up following the “One Health” approach, which recognizes that the human health is tightly connected to the health of the animals and environment.

Finally, the Organizing Committee would like to thank the authors and the presenters for their contributions. A special thanks to Prof. Sabina Failla for her outstanding job as Scientific Secretariat of the conference and as Managing Editor of this volume and to Prof. Massimo Cecchini for the digital management of the online conference tools.

Together with Prof. Remigio Berruto, CIGR president, Prof. Danilo Monarca past president of Italian Association of Agricultural Engineering (AIIA), the 6th International Conference Ragusa SHWA Steering Committee invite you to the next edition of the conference, in September 2023, in the late Baroque city of Ragusa Ibla, in the southeastern Sicily, Italy.

January 2022

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Quantification of Trunk Postures Among Fruit and Vegetable Pickers in Sardinia

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Abstract. Throughout the world, fruits and vegetables are grown and harvested through labor-intensive work tasks. The work involved with manually harvesting agricultural produce expose workers to awkward trunk postures that have been associated with the development of musculoskeletal disorders. Row crops, grown close to the ground, are especially task intensive and involve physical labor that has been associated with increased risk of low back injury. The purpose of this study was to quantify trunk postures during manual harvesting of fruits and vegetables.

Vegetable and fruit pickers were recruited from a farm in Sardinia, Italy. Participants wore an accelerometer-based trunk motion logging system for approximately two hours while harvesting eggplants (9 workers) and strawberries (7 workers). The posture data was processed in a custom MATLAB script. The magnitude, frequency, and time spent in four categories of trunk postures were assessed.

Pickers had a mean age of 39.4 years (SD, 13.6) which included 7 females and 9 males. Eggplant pickers had a mean maximum trunk posture of 82° compared to 93° for strawberry pickers. The eggplant pickers spent the majority of their work time between 0° and 30° of trunk flexion, while strawberries pickers spent the majority of work time in 60° to 90° of trunk flexion. The frequency of the trunk postures were also different between workers harvesting eggplant and strawberries. Eggplant workers spent an average of 27 s in trunk flexion during picking as compared to 49 s for strawberry workers. In addition, there were significant differences in the time spent in the four defined posture categories.

The results of the study have demonstrated that an accelerometer-based trunk motion logging system was successful in quantifying trunk postures among fruit and vegetable pickers. Quantifying posture data among fruit and vegetable pickers can be used to establish a baseline to assess, develop and manage improved work designs that reduce the risk of low back stress during manual harvesting.

Keywords: Low back injury · Agriculture · Exposure assessment · Fruit and vegetable picking

M. Biocca et al. (Eds.): SHWA 2020, LNCE 252, pp. 3–10, 2022.
https://doi.org/10.1007/978-3-030-98092-4_1

1 Introduction

Low back disorders a major occupational health problem facing the agricultural workforce [1, 2]. Manual harvesting of fruit and vegetables often requires workers to maintain a flexed or stooped posture, which place agricultural workers at a higher risk of sustaining a low back disorders [3–5]. Row crops, grown close to the ground, require workers to sustain stooped or awkward work postures during planting, weeding, and harvesting. The physical risk factors associated with these work activities have been strongly associated work-related musculoskeletal disorders of the low back [6].

Field-based health and safety assessments are often used to identify work tasks that involve high physical loads and anatomical postures that expose workers to high risk of work-related low back disorders. Beyond the identification of these risks, it is important to also quantify the magnitude and temporal components of the physical exposures. Although field-based assessments within agriculture have been conducted, the risk assessment tools often lack high levels of accuracy and precision when conducting work-related musculoskeletal risk assessments completed over the duration of a workday.

Advancements in technology have resulted in low cost, miniaturized, wearable sensors that detect both physical and physiological signals of the body. Wearable technologies are a novel method to conduct physical risk-assessments for musculoskeletal hazards in the workplace. Although wearable devices have been used to measure occupational physical and physiological workloads, these technologies are not often used in the agricultural sector. Thus, it is necessary to demonstrate the usefulness of wearable sensor systems in terms of data produced, simplicity in the field, and acceptance among agricultural workers when performing field-based risk assessments.

Currently, researchers and practitioners frequently use observational tools that are easily administered but often only quantify the presence of exposures at a single point in time, potentially overestimating or underestimating the magnitude, frequency, and duration of the exposure. The latest wearable technology, however, has the capacity to collect and store physical (and physiological) data from large samples of workers and during an entire work shift (8 h) to accurately quantify the components of exposures of interest. The primary purpose of the present study was to demonstrate the quantification of trunk postures during fruit and vegetable harvesting among agricultural works in Sardinia, Italy.

The aims of the present study were to 1) characterize trunk postures of agricultural workers performed during vegetable and fruit pickings using wearable technologies, and 2) to assess the usefulness of wearable microsensors to assess trunk postures during agricultural field research.

2 Methods

An agricultural organization that produced several varieties of fruits and vegetables in Sardinia, Italy and their farmworkers were recruited for this study. The research methodology was reviewed and approved by the university Institutional Review Board and farmworkers that agreed to participate provided informed consent. The farm that was involved in the study was familiar with the university research team prior to their participation. Participants wore an accelerometer-based trunk motion logging system (Zephyr Bioharness™ 3, Zephyr Technology Corporation, USA) (see Fig. 1) for approximately two hours while harvesting eggplants (9 workers) or strawberries (7 workers). Demographic data collected included age, height, weight, sex, produced harvested, and work experience. Each of the participants wore a chest mounted logging device during the initial calibration procedure (Fig. 3a), during 120 min of picking (Fig. 3a and b), and during the post-calibration procedure.

The trunk posture data from the Bioharness™ 3 was processed in a custom MATLAB script. The magnitude, frequency, and time spent in four categories of trunk postures were assessed. The trunk posture categories assessed included Category 1, trunk extension to upright (<0° to 0°), Category 2, (>0° to <30°), Category 3 (≥30° to ≤60°), and Category 4, (≥60°), see Fig. 4. The total time picking, frequency of picking task (expressed as cycles in trunk flexion and extension per hour), average cycle time, and average maximum trunk flection per cycle were quantified.

The study design was descriptive involving one farm, two crops, and a limited number of subjects. Thus, statistical differences between the dependent variables as not assessed (Fig. 2).

Fig. 1. Zephyr Bioharness™ 3 with the closeup of the module housing the datalogger and tri-axial accelerometer.

Fig. 2. Research team attaching Bioharness™ 3 to strawberry picker**.**

(a) **(b)** **(c)**

Fig. 3. a, b, c. Study participant (3a.) shown during calibration procedure to establish a neutral 0° posture with plumb line through ear, shoulder, hips and ankle. Typical stooped working postures are shown for eggplant (3b.) and strawberry (3c.) pickers during data collection.

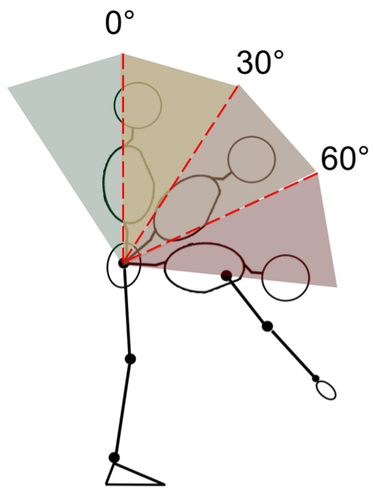

Fig. 4. Four posture categories used in the analyses of posture risk.

3 Results

Pickers had a mean age of 39.4 years (SD, 13.6) which included 7 females and 9 males. The mean time spent picking during the data collection period was 102.1 min (SD, 5.6) for eggplant pickers and 99.5 min (SD, 8.5) for strawberry pickers Eggplant pickers had a mean maximum trunk posture of 82° compared to 93° for strawberry pickers. The eggplant pickers spent the majority of their work time between 0° and 30° of trunk flexion, while strawberries pickers spent the majority of work time in 60° to 90° of trunk flexion (Fig. 5). The frequency of the trunk postures were also different between workers harvesting eggplant and strawberries. Eggplant workers spent an average of 27 s in trunk flexion during picking as compared to 49 s for strawberry workers. In addition, there were large differences in the mean task frequencies with eggplant workers averaging 132 cycles per hour while strawberry workers completed 73 cycles per hour. One task cycle was defined as the duration workers were stooped while picking, that is, from beginning of picking to end of cycle when the worker deposited the product in the bin or basket.

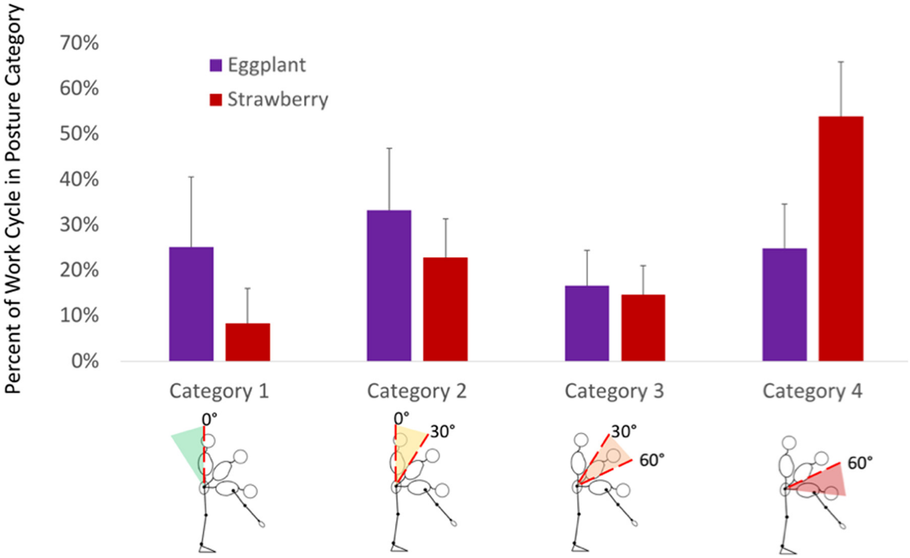

Fig. 5. Percent of work cycle spent in each posture category for eggplant and strawberry pickers.

4 Discussion

The present study described the quantification of trunk postures during fruit and vegetable harvesting among agricultural works in Sardinia, Italy. The study results identified clear differences in the trunk postures between eggplant and strawberry pickers with regard to the magnitude of trunk flexion, duration of time picking in high risk posture categories, average cycle times and mean time for a picking cycle. The results were expected given that the tasks involved with picking strawberries are quite different than that of eggplants.

Strawberry picking involves a smaller product that is typically grown closer to the ground than eggplant which is larger and hangs on a taller plant. Additionally strawberries were picked until the worker was able to fill a small plastic carton that held approximately 20–25 pieces of fruit. Once the plastic carton was filled, the worker would stand upright and place the plastic bin on a wheeled cart. The total cycle time to fill the plastic carton was approximately 50 s. In contrast, eggplants were picked by searching the plant for ripe produce and cutting them with a hand snip. With the cutting snips in one hand and holding eggplants in the other, workers were limited to hold four eggplants before standing upright to dump them into a large bin pulled in a wheeled cart. Thus, the mean cycle time was only approximately 25 s; half that of strawberry harvesting. The differences in these picking methods resulted in a greater magnitude of trunk flexion in a stooped posture for a greater percentage of the task cycle for strawberry workers as opposed to eggplant pickers.

The literature has consistently indicated that stooped postures expose a large segment of agricultural workers to a high risk of developing a low back disorder as well as the need to address these issues through better work methods [3]. Studies assessing the effects of stooped work tasks on the muscle activity and kinematics of the low back, suggest that short, frequent rest breaks during sustained stooped work tasks may be beneficial to the recovery of passive musculoskeletal tissues [5]. Additionally, in a study of rest break interventions among commercial strawberry pickers, researchers reported significantly less severe musculoskeletal symptoms among workers with 5-min breaks every hour versus control workers not receiving the breaks [7].

A secondary aim of this descriptive study was to assess the usefulness of wearable microsensors to assess trunk postures during agricultural field research. In the past decade, there has been greater use of wearable measurement systems to assess occupational physical and physiological workloads [8]. A *useful* wearable measurement system for the researcher or practitioner may be characterized as requiring minimal time and resources to operate and one that obtains quantitative data. The measurement system should be easy to attach to the individual, have a short, uncomplicated calibration procedure, and elementary data processing techniques. The Bioharness™ 3 physical and physiological monitoring system demonstrated these characteristics and was relatively easy to operate in our field conditions. Setup and calibration required approximately 10 min per subject and the harness was reported to be comfortable by workers during the two-hour data collection period. In addition to quantifying trunk posture, the Bioharness™ 3 system also measures heart rate and activity levels, which could provide beneficial information to health and safety professionals interested in a physiologic metrics related to work-environment interactions [9]. The ease of use of a wearable measurement system enables researchers and practitioners the ability to quantify trunk postures pre- and post-interventions to evaluate effectiveness in reducing extreme trunk postures during work tasks. A recent study of forestry loggers assessed the magnitude and duration of trunk postures during various logging tasks to assess biomechanical loads using the same measurement system described in the present study [10].

The data generated from the present field-based descriptive study of trunk postures among fruit and vegetable pickers in Sardinia will be used in the development of work design solutions to reduce potentially harmful physical exposures experienced during manual harvesting tasks. The quantification of frequency, duration, and magnitude of awkward trunk postures during stooped work activities is an important step in the development of safer and effective work design solutions.

Acknowledgements. The authors wish to thank Prof. Lelia Murgia and Dr. Gabriele Sara for their valuable assistance in data collection during on-farm activities. Sincere thanks also goes out to the farm management and the farmworkers for their willingness participate in these research activities. This research was supported by the High Plains Intermountain Center for Agricultural Health and Safety CDC/NIOSH Grant No. U54OH008085 and the Mountain and Plains Education and Research Center CDC/NIOSH Grant No 254-2012-M-52941. Its content is solely the responsibility of the authors and does not necessarily represent the official views of CDC/NIOSH.

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Image Analysis for Ergonomic Risk Assessment for Rope Arborists

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Abstract. The work of rope arborist involves multiple risks, as falling from above, the risk of cutting for the use of chainsaw or physical risks (noise and vibrations) that cause professional diseases.

Ergonomic risk also plays an important role. The tree climbers perform a work getting not vertical postures to maintain a stable position and performing repetitive movements due to the use of the saws and chainsaw.

This work aimed to assess the ergonomic risk for rope workers on trees by analyzing the image and applying indices.

The assessment were carried out during pruning activities in fruit chestnut trees in Viterbo province and the postures of 3 operators have been analyzed from an ergonomic point of view.

To obtain this evaluation, 100 observations were examined, and image analysis was done using an Ergofellow 3.0 ergonomic analysis software applying two indices for postural analysis: REBA (Rapid Entire Body Assessment) and RULA (Rapid Upper Limb Assessment).

From the data analysis, the diversity of the calculation process emerged; the two indices are not interchangeable and return a different level of risk for the same task: MEDIUM with action required for REBA and "further study required and rapid changes applied" for RULA.

The two indices REBA and RULA were not designed to analyze rope work.

In conclusion, a specific index for rope workers is desirable, which considers postures and work equipment. This work introduces the foundations for the development of this rope worker's risk index.

Keywords: Tree climbing · Ergonomic · Work positions · REBA Index · RULA Index

1 Introduction

The profession of the arboriculturist on ropes involves many risks, from the most intuitive ones such as the risk of falling from a height [1] and the risk of being cut during the use of the chainsaw [2], to the more subtle ones such as physical risks (noise and vibrations) that cause occupational diseases.

More and more attention is being given to this area, due to the increase in the number of operators who are engaged in this work activity. This phenomenon is due to

M. Biocca et al. (Eds.): SHWA 2020, LNCE 252, pp. 11–18, 2022.
https://doi.org/10.1007/978-3-030-98092-4_2

the increasing attention to the planning and management of trees in the city both for safety and ecosystem services issues. This increase in operators and interest also corresponds to many accidents, given the dangerousness of the activity [3–6].

In the scientific field more and more works are dealing with this sector, going from the interaction between the equipment/operator and the tree, especially regarding the anchorage point [7–9], to certain operations such as rigging [4], to safety with the study of knots used during the same practices [10, 11] or those for the operator's insurance, friction knots, or even the study of the compatibility of certain PPE [12], up to safety standards and surveys among operators to define, for example, the degree of training, equipment used or injuries suffered [6, 13, 14].

In this panorama and given the multitude of risks, the ergonomic one is also a very important factor [2] in this working sector, as the operator performs a demanding physical work and often in positions that are not perfectly vertical, having to rely on ropes and other equipment to maintain a stable position (citing tree climbing questionnaire). The arboriculturist is found cutting with saws or chainsaws, to carry out pruning and controlled felling (rigging) repeating movements and postures that have never been evaluated objectively to quantify the associated risk.

The aim of this work was to evaluate the postures assumed with the technique of tree climbing, during pruning operations of fruit chestnut trees, through image analysis and using two established indices: REBA [15] and RULA [16], both valid for the analysis of postures at work but with different methodological approaches: the first refers to the whole body, while the second mainly to the upper limbs.

2 Materials and Methods

The work sites where the pruning activities were carried out are two chestnut groves located on Mount Cimino, in the province of Viterbo. Three operators were required for the survey: one on the ground for the assistance and possible rescue of the worker (therefore qualified to climb trees and trained to recover the injured person) and an operator in the canopy equipped with a video camera in charge of filming the third operator while he was carrying out the pruning operations. The equipment used is the usual tree climber's equipment, which refers to the provisions of the Italian Consolidated Law on Safety at Work D.lgs 81/08 and consists of access and positioning devices, individual protection and hand and power cutting tools such as hacksaws, telescopic poles, and chainsaws. The SRT (Single Rope Technique) ascent technique was used. Once the operator reaches the highest position, he secures himself with a safety lanyard and installs the work rope, a DdRT (Doubled Rope Technique) system; then, he releases himself from the single rope system with which he ascended and is ready to move inside the canopy, reaching the branches to be eliminated or on which to make the return cut. Each time he has to make a cut, the operator secures himself with the lanyard, for double safety [17]. The second operator on the plant performs the same access and positioning procedure and then reaches a suitable position to film the cutting operator. The position should be as much as possible at the same height as the other operator and positioned laterally, so that the working angles can be best interpreted during image analysis. Pruning operations were performed with hand and powered tools.

The assessment of ergonomic risk for workers can be easily carried out using objective indices that place the operator within risk categories, from null to high (depending on the type of index). The choice of index must be made according to the type of work, so that it considers the limbs more subject to effort or repetitive work rather than impulsive. After accurate bibliographic research, no specific index emerged for the assessment of the ergonomic risk of ropeway workers, so it was decided to use two well-established indices for postural analysis: REBA and RULA. Both indices consist of calculation matrices that, depending on the postures assumed by the operator, return a score [15, 16] that increases according to the lack of ergonomics during work. The video analysis was carried out with Ergofellow 3.0, linera test version, with which the ergonomic indices REBA Index (Rapid Entire Body Assessment) and RULA Index (Rapid Upper Limb Assessment) were calculated. The REBA index makes it possible to carry out a postural assessment of the risk of muscular-skeletal pathologies of the upper limb and neck using the REBA method (Rapid Entire Body Assessment). The REBA method is an internationally used method that allows a quantitative analysis of the main risk factors to which a worker may be subject. The method is to be used in a context of general postural assessment; the fundamental output of the REBA method is to identify situations/conditions of work that could lead to serious diseases in workers. The RULA index was developed to investigate upper extremity musculoskeletal risk exposure during work. Part of the development took place in the garment industry, where the assessment was made for workers who performed tasks including cutting while standing at the workstation, using a variety of sewing machines, trimming, and performing inspection and packing tasks. RULA was developed by evaluating the postures adopted and the forces required and for operations while working [16]. Images were the most important tool for posture and ergonomic risk analysis. They provided all the information for calculating the angles of the limbs with respect to the body, torso torsion, head tilt, and weight bearing on the limbs. It was necessary to find them exactly at the same height as the operator to ensure that the perspective from below did not alter the perception of the angles, since the software requires very detailed information, and the input must be as accurate as possible. In order to avoid gross errors in the evaluation it was preferred to film the tree climber through a second operator positioned in the canopy. The images were taken with a Panasonic Lumix tz 80 digital camera (1,920 × 1,080 pixel, 50 fps). 100 observations were taken. The REBA and RULA indexes were calculated for each of them, and the Pearson correlation and covariance were observed for the comparison of the indicators.

3 Results

From an ergonomic point of view, the postures of three operators engaged in the pruning of tall trees using the technique of tree climbing were analyzed. Ropeway operators generally use equipment that is not very heavy, except for particular controlled felling tasks, which were not taken into consideration because they cannot be classified as repetitive works that require operators to repeat the same movement many times during the working day. Controlled felling is reserved for experienced and well-trained operators who, above all for their own safety, cannot and should never put the speed of execution of the work ahead of their own safety and the tranquility of the entire team assisting them. In pruning work, on the other hand, it is possible to find good procedures which, while always requiring the utmost attention, lead the operator to repeat the same gesture many times, albeit with slight variations in angle and positioning. In particular, the use of the pruning saw is the most frequent working situation (Fig. 1) and valid for analyzing the ergonomic risk for the operator. Various postures have also been considered for the use of the chainsaw, but given the particular attention that its use requires, the work rhythms and therefore the repetition of movements are not comparable to the previous type of tool (Fig. 2).

Fig. 1. Example of posture during pruning with handsaw.

Fig. 2. Example of processed image for identifying limb angles during pruning.

From the analysis of the data, it emerges the diversity between the indices both in the calculation process and in giving a different weight to the various postures according to the risk class. Even though the maximum values are different, the final figure places the operator in two different risk classes: MEDIUM with action required for REBA and "further investigation and rapid application of changes required" for

RULA. The distribution of the values obtained is also substantially different, which confirms what is underlined by the Pearson and Covariance coefficients, both close to zero (Table 1): the two indices are not interchangeable but return a different level of risk for the same task.

Table 1. Average, Correlation and Covariance of the REBA RULA indices

Index	Average ± SD	Correlation	Covariance
REBA	7.01±1.59	0.10	0.13
RULA	6.27±0.78		

It is evident that REBA index, which takes into consideration the whole body, returns for the type of work of pruning on ropes average values in its risk scale, while RULA, which considers only the upper part of the body, returns a risk value that is almost always high (6.27 on a scale of 7- Fig. 3, 4).

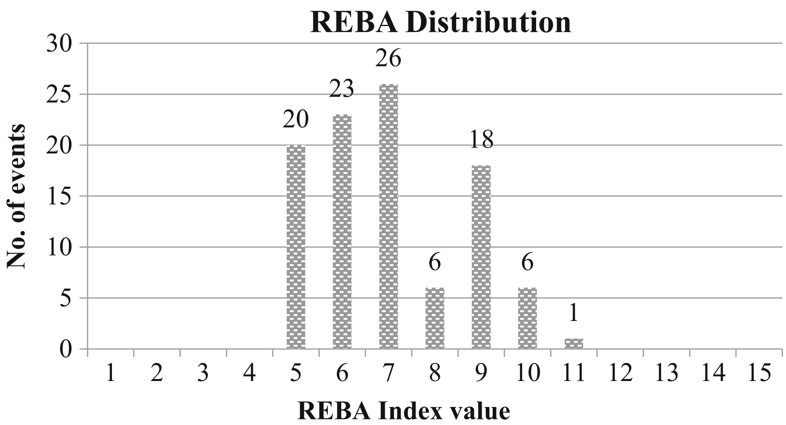

Fig. 3. Distribution of risk classes calculated for the REBA index.

In order to have a subjective term of comparison on which of the two indices is more adequate, a third sample was introduced, i.e., all the images were evaluated by 6 expert operators who gave a judgment by assigning a value from 1 to 11 according to their personal judgment of ergonomics of postures (Fig. 5). This sample is considered a useful judgment of comparison, as it is expressed by people who are experts in the type of work.

To compare the three data sets, they were normalized, and covariance was calculated between the REBA, RULA, and values provided by the expert operators. The analysis of covariance returns a more similar value between RULA index, and the values assigned by the expert operators, although the risk level is more similar to the REBA index values (Table 2).