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## Assessing the Effects of Biomechanical Overload on Dairy Parlor Workers' Wrist: Definition of a Study Approach and Preliminary Results

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### Abstract

**Background:** Dairy milking is a demanding work task that has been associated with hand and wrist musculoskeletal disorders. Clinical approaches to identify the early effects of musculoskeletal disorders among dairy parlor workers' wrist have not been well defined.

**Objectives:** The purpose of this pilot study was to develop a study protocol that would assist in the identification and quantification of hand and wrist disorders among dairy workers that perform tasks in the dairy parlor. Additionally, such a study protocol was needed to perform relatively rapid assessments of the wrist/hand on large samples of dairy workers.

**Methods:** Fourteen dairy parlor workers were assessed for i) upper limb symptoms and work history through questionnaire, ii) a physical examination of the upper limb and in particular wrists and iii) wrist ultrasonography. An additional 21 unexposed paired participants (the control group) also participated in the data collection.

**Results:** The study results identified two ultrasound acoustic windows characterized by the highest predictive value for alteration of the wrist's structure. Study results indicated an impairment of the distal median nerve in structure and mobility and impairment of the distal tendon of the muscle extensor carpi ulnaris that included dislocation and frank damage.

**Conclusions:** This study identified at least two acoustic windows that should be assessed with ultrasound studies on larger groups and in prospective periodical health surveillance of dairy workers. The study confirmed the wrist was at risk for biomechanical stress among workers conducting milking tasks in the dairy parlors.

### Keywords

Milkers; ultrasonography; study protocol; wrists overload

## 1. Introduction

Agriculture is a very demanding activity, and its association with several musculoskeletal disorders is well known. The musculoskeletal symptom most frequently reported by agricultural workers is low backpain (LBP) [1]. The proportion of farmers reporting LBP varies between 31% [2] and 50% [3], with the highest prevalence among those engaged in agricultural activities for more than 25 hours per week [4]. Other studies have indicated a high prevalence of musculoskeletal symptoms among farmers for shoulders (25.9%), knees (23.6%) and the cervical spine (22.4%) [5].

A systematic review of literature on musculoskeletal disorders in agriculture concluded that the spine is the most studied body region, followed by lower and upper extremities. This review highlighted the necessity to conduct studies focused on specific types of farming, physical exposures specific to the workers' tasks and specific body parts [8].

Among agricultural work activities, dairy farming is of particular interest in occupational medicine because of the variability of tasks and exposure to a variety of biomechanical risks. There are evidences that both male and female workers perceive the milking routine tasks performed repetitively to cause more musculoskeletal discomfort than heavier tasks performed on a non-routine or seasonal basis [9]. As for dairy workers, researchers have identified heavy lifting loads and repetitive motions contributing to adverse musculoskeletal effects on the lumbar spine, shoulders, necks, hands and wrists [10]. According to existing literature [11, 12], the milking tasks requiring particular hand and wrist intensive efforts in terms of the repetitive physical exposures are:

1. Pre-dipping of the udder (Fig. 1): this subtask involves disinfection or cleaning of the teat before milking. This process reduces the bacteria, particularly those from the environment such as *E. coli*, very often present on the teat. The teats can be dipped in disinfectant using a dip cup or sprayed. Both methods are acceptable as long as the whole teat is covered. This task does not require the worker to perform significant physical effort, although wrist posture can be critical due to the repetitiveness of the task and the need of covering the entire teat with disinfectant (Fig. 1).
2. Wiping/stripping phase (Fig. 2): The wiping task is normally performed at different points of time in the process. In some countries, such as Italy, wiping and stripping (stimulation of the udders) phases are performed simultaneously, whilst they are separate phases in other countries. Using a dry towel to wipe-off and dry the teats thoroughly is particularly important so the entire teat and tip of the udder is clean. The fore-stripping task (2–3 squirts of milk from each teat) is also important to check the presence of abnormal milk and stripping represents the best way to detect mastitis. In this phase, the worker strips each teat at least once in order to achieve the results just described above. Therefore, considering an average of 50 cows milked per hour, it is estimated that the workers perform this subtask at least 250 times per hour. The repetitiveness of this activity makes it one of the most critical factors in the overload of the upper limbs (Fig. 2).

3. Attaching of the milking cluster (Fig. 3): After drying the teats, the milking cluster is attached to the cow's teats. This operation is very important because the risk of new infections depends on the percentage of air leakage during the attachment. After attachment, the unit is aligned in order to hang squarely on the udder with a slight forward pull. This phase appears to be the most physically demanding for the upper limbs of the workers since it requires the milker to attach each of the four section cups of the cluster onto a teat. This task involves repetitive flexion and pronation/supination of the wrists and it has been considered one of the most strenuous tasks [13], requiring approximately 10–15% (range 5–25%) of the maximum voluntary contraction (MVC) of all upper extremities, shoulder and lower back [14]. The effort mainly depends on the weight of the milking unit (estimated from 1.5 to 3.5 kg), therefore a significant reduction can be achieved using less heavy milking units [14] or providing the workers with arm support that reduces the load on the biceps [15] (Fig. 3).
4. Post-dipping of the teats: This task is similar to the pre-dipping task and serves to eliminate bacteria transferred onto the teat during the milking process. Post-milk teat disinfection can be achieved by applying a suitable disinfectant to the teat immediately after every milking. As with pre-dipping, teats can be dipped in disinfectant using a dip cup (bottle) or spray.

In each phase, parlor design and anthropometric and cows' body characteristics also affect the levels of physical overload [14]. The three common milking systems used in Italy include the rotary, the parallel and the herringbone design systems (Fig. 4).

In each of the three parlor configurations, workers perform the same four primary milking tasks described above. Although workers may rotate from station to station or from cow to cow, it is evident that awkward postures, repeated exertions, velocity of wrist movements of flexion and extension, radialulnar deviation and are the main biomechanical risks affecting the upper limbs [16–18]. The introduction of the new loose housing milking systems has increased hand wrist extension and repetitiveness [16] as well as static load but reduced muscular rest [19]. Industrialization has also brought about an increase of the time spent in milking activities and therefore the levels of workers' exposure to these risk factors [13].

The main symptoms resulting from the above-mentioned exposures are tingling, numbness, pain and/or reduced muscle strength [13, 20]. In some cases, symptoms are accompanied by evidence of entrapment of the median nerve at the level of the elbow and the wrist (Carpal Tunnel Syndrome) [16, 21–23]. In this light, the median nerve seems to be the most sensitive target of the repetitive forceful handwork [24], but other soft tissues of the area may be affected [25].

Most of the available studies on workers' wrists and nerves have been conducted with ultrasound examination, which seems to be highly sensitive for detecting abnormalities, but unable to provide information regarding the severity of the changes [27]. For this reason, an ultrasound approach must be accompanied by physical examination and symptoms reported by individuals [28].

Available data suggest the existence of a significant health risk, but the information comes from very small study groups [8, 13, 14, 17, 19, 20]. The main reasons for this situation are, from one side, the well-known poor access of rural workers to health surveillance at the workplace, and, from the other side, the fact that using ultrasonography is still time consuming, not easy to conduct at the workplace, and therefore non-adequate for screening activities.

As highlighted in other studies, there is paucity of data describing standardized scanning methodology and standardized definitions of Ultrasound pathologies [28]. Therefore, there is a growing need for additional studies specifically focused on defining a screening method that is able to allow the involvement of larger groups of workers and to perform routine health surveillance of workers at the workplace.

The aim of this cross-sectional pilot study was to define a study protocol adequate to identify hand and wrist disorders among milking parlor workers, and suitable to conduct a relatively rapid assessments of the wrist district even on large groups of workers.

## 2. Methods

The present pilot study was conducted on a group of 14 male dairy parlor workers selected among the enterprises being provided with occupational health surveillance by the International Centre for Rural Health of the University Hospital San Paolo of Milan, a World Health Organization Collaborating Centre. Twenty-two healthy male participants were selected as a control group, paired with the exposed participants for gender, age and ethnicity. None of the control participants had ever been engaged in agricultural activities or jobs requiring manual handling of heavy loads or repetitive hand motions.

The experimental approach, approved by the Human Ethics Committee of the University Hospital San Paolo, was based on three components: 1) the identification of workers' symptoms through the administration of a questionnaire, 2) ultrasound imaging (ultrasonography) of the wrist region performed with portable ultrasound instrumentation, and 3) a physical examination of the upper limb including standardized clinical tests. Before participation, the involved participants had been informed about the approach and the aims of the study and provided informed consent.

All the following activities were conducted at the workers' workplace, in rooms made available by the employers and declared adequate to the study by the research group.

Since most of the milkers were migrants, with a low educational level, the questionnaire was completed with a graphic representation of a human body on which the workers were asked to indicate the body areas where symptoms such as pain, tingling/numbness, weakness, night symptoms were present. In addition to symptoms, the following information was collected from all participants: nationality, gender, age, education level, occupational history, body weight, height, exercise habits, handedness, duration of present job, hours worked per day, and the presence of manual materials handling tasks during the work shift. We also asked the milkers to estimate the number of animals milked per day and about the type of milking

system (rotary, parallel or herringbone) and milking cluster characteristics they used during their work-shift.

The ultrasonography (US) examination was performed by a sonographer according to the European Society of Musculoskeletal Radiology's protocol (ESSR) [29, 30], with the examination of more than 20 body areas adequate to investigate specific wrist's districts with ultrasonography ("acoustic windows") in both wrists (Table 1). The ultrasonography equipment (Venue Scan, Venue 40, GE Healthcare®) allowed the researchers to store the examination for further evaluation and discussion with other hospital experts in the final evaluation of all cases.

Wrist was investigated through the determination of the following parameters for each acoustic window selected: US texture, shape, range and pattern of motion. For the classification of the ultrasound study results, we adopted the grading system proposed by Yoon et al. [31] and by Wakefield et al. [28]. In particular, differing from the original protocol, we divided the results in two main categories (0 = normal/expected and 1 = abnormal). This in order to give, in the frame of a preventive approach, particular attention to preclinical and very early changes, fundamental for secondary prevention. However, since a dichotomous classification does not discern the severity of changes in the ultrasound signal detected, the following classification criteria were created for nerve and tendon findings

- Tendons: Category 0: a) normal. Category 1: a) heterogeneity of the ultrasound signal in the texture, b) not permanent dislocation c) increased anechoic signal of the synovial space. Category 2: a) a discontinuity in the ultrasound signal of the texture and a permanent dislocation.
- Median nerve Category 0: a) normal. Category 1: a) Increase of area hypoechoic and altered fibrillary pattern when median cross-sectional area is between 10 and 15 mm<sup>2</sup> in the median nerve, b) immobility without changes of shape. Category 2: a) Immobility with changes of shape and increase of area hypoechoic and altered fibrillary pattern when median cross-sectional area is more than 15 mm<sup>2</sup> in the median nerve.

All milkers and controls underwent a clinical examination of the upper limbs, performed by an occupational health physician. The clinical examination included an evaluation of symmetrical posture of the clavicles, hypersensitivity to palpation, hyperextension and hyperflexion of the fingers; Finkelstein test, Phalen's maneuver; Tinel's sign, wrist radial and ulnar reflexes, elbow, wrist, finger range of motion (ROM), and sensitivity to an upper limb tension test of the median nerve [32]. Since most of the available data suggest an impairment of median nerve, we completed the physical examination of the workers with the pinch-holding-up activity (PHUA) test [33]. We chose this test, among the others available for the purpose [34–36], because pinching activity seems to be particularly significant in milking tasks. Only one test was applied among the various tests available because of the need of defining a screening procedure, to be easily and rapidly performed at the workplace. Evaluation was performed asking the workers to lift with the pulps of thumb and index finger to 5 cm above the table top, a small metal clip for 5 seconds. Results were dichotomously classified (0 = normal; 1 = reduced gripping capacity).

The majority of the variables from the questionnaire and clinical examinations were dichotomous and classified as either absent or present.

Statistical analyses were performed with SPSS PC version 22. Differences between groups (milkers and controls) were assessed with Chi Square and Fisher tests with statistical significance set at  $p = 0.05$ .

### 3. Results and discussion

We studied a group of 14 dairy parlors workers and 22 controls. There were no significant differences between exposed and controls for the potential confounding factors of age, gender, and ethnicity (Table 2). The milkers were engaged in their work activities for periods ranging from 0.5 to 40 years (median = 15.5 years).

#### 3.1. Symptoms

Symptom histories indicated that a higher proportion of dairy parlor workers versus controls reported wrist pain (3/14 versus 0/24 for controls), numbness and/or tingling in the fingers (4/14 versus 1/24), weakness in the hand (3/14 versus 0/24), nocturnal pain or paresthesia (3/14 versus 0/24). None of the proportional differences in symptoms were statistically significant between the two groups. The lack of statistical significance may have been at least partially due to the small sample size of the study groups. The physical examinations revealed that a higher and statistically significant ( $p < 0.05$ ) proportion of milkers had a reduction in pinching capacity compared to controls, whilst clinical testing failed to show any difference between the groups (Figs. 5 and 6).

#### 3.2. Ultrasonography

The main findings were:

- increase of the synovial space at the Radiocarpal & Mid carpal joints Left ( $p = 0.020$ ), Right side ( $p = 0.013$ )
- echotexture alterations, such as fibrillary pattern disorganization, intra-tendon gaps, permanent and non-permanent dislocation at the extensor carpi ulnaris tendon: L side ( $p = 0.00$ ) and Right side (0.013). As for the degree 2 lesions, we observed dislocations (2L) and ruptures (2L) in the ECU tendon (Figs. 6 and 7 respectively). increase of the transversal cross sectional area (Fig. 9a) as compared with a normal nerve (Fig. 9b), hypoechoic and altered fibrillary pattern and changes of shape and mobility at the median nerve left side ( $p = 0.000$ ) and right side ( $p = 0.003$ ).
- As for the degree 2 lesions, we observed immobility and median cross sectional area more than  $15 \text{ mm}^2$  in the median nerve (2L and 2R).

Our data are in agreement with literature [16, 21–23] and suggest that the median nerve tract in the carpal tendon and the extensor carpi ulnaris tendon are the components most vulnerable to the biomechanical overload associated with milking tasks. Moreover, four milkers presented with rupture (2) or dislocation (2) of the extensor carpi ulnaris tendon. The reduction of wrist stability brings about an alteration in mobility of the

median nerve, thus increasing the wrist sensitivity to biomechanical overload because of a reduced efficiency of the painful limb motions [37]. The reduced muscular and ligamentous stabilizing action increased stress that may affect the carpal nerve segments with consequences on endoneural blood flow [38]. Therefore, gripping capacity can be affected and, according to Iida et al. [39], has the potential of contributing to nerve lesion and arthritis. Overall, the main findings of the present study include an increased incidence of changes in the median nerve in the upper limb and musculoskeletal disturbances primarily at the distal tendon of the extensor carpi ulnaris in workers engaged in milking tasks.

The statistically significant reduction in the fine hand manipulating capacity, assessed by the pinching test, might be consequent to both median nerve and tendon impairment. These data confirm that wrist may be the target of the biomechanical risk present in milking activities and suggest the need of further research on matter. Another important finding was that ultrasonography showed alterations of variable levels of severity even in the presence of very mild symptoms or in fully asymptomatic participants. This was the case with the increase in the median nerve cross sectional area (Fig. 8) and tendon dislocation (Fig. 7) which have been observed in participants who did not report any major symptom of wrist impairment. This might suggest that an ultrasound assessment may represent a valid tool in the identification of occupational diseases in a very early stage, making it a possible for secondary prevention strategies of neurovascular and musculoskeletal disorders to be introduced. Since the lesions we observed were present only in two acoustic windows (extensor compartment-6 and flexor compartment-3 (carpal canal), we can speculate that these windows have the greatest positive predictive value for detecting wrist diseases in the conditions of exposure considered.

Therefore, the main outcome of this study has been the creation of the possibility of simplifying the ultrasonography approach for screening dairy parlors workers' wrist. In fact, the definition of two acoustic windows and the use of a portable device might overcome the limitations currently existing for conducting such screening in field studies, which is the time required to perform ultrasonography to multiple acoustic windows. Moreover, this approach is suitable also for workers' periodical health surveillance carried out by occupational physicians according to European Union law.

In particular, the approach briefly consists of the administration of a symptoms questionnaire, a clinical test completed with the pinch-holding-up activity (PHUA) test and ultrasound evaluation of the two putative windows considered as the most predictive for the detection of wrist disorders (extensor compartment-6 and flexor compartment-3). Of course, we are well aware that the small size of the study groups may have affected our results; however, results of this pilot study were consistent with other similar studies. There is a need to these results to be confirmed on larger population samples.

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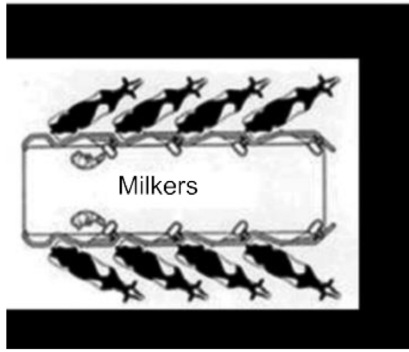
**Fig. 1.**  
Dipping subtask in a parallel milking parlor; Lombardy region, Italy.



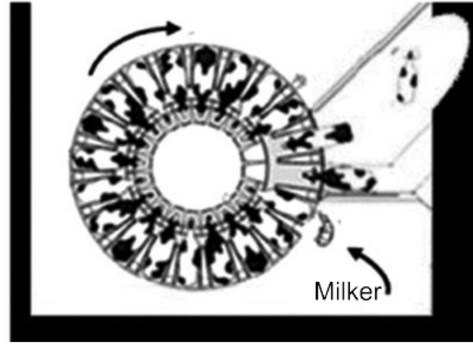
**Fig. 2.**  
A milker performing the stripping/wiping subtask in a herringbone milking parlor;  
Lombardy region, Italy.



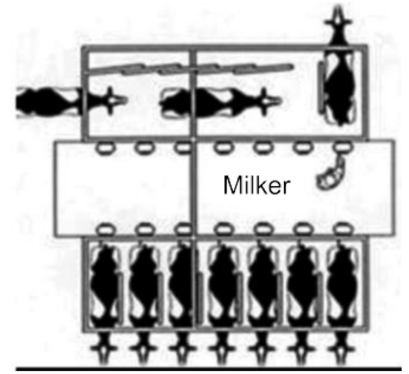
**Fig. 3.**  
A milker performing the attaching phase in a rotary milking parlor; Lombardy region, Italy.



a) Herringbone

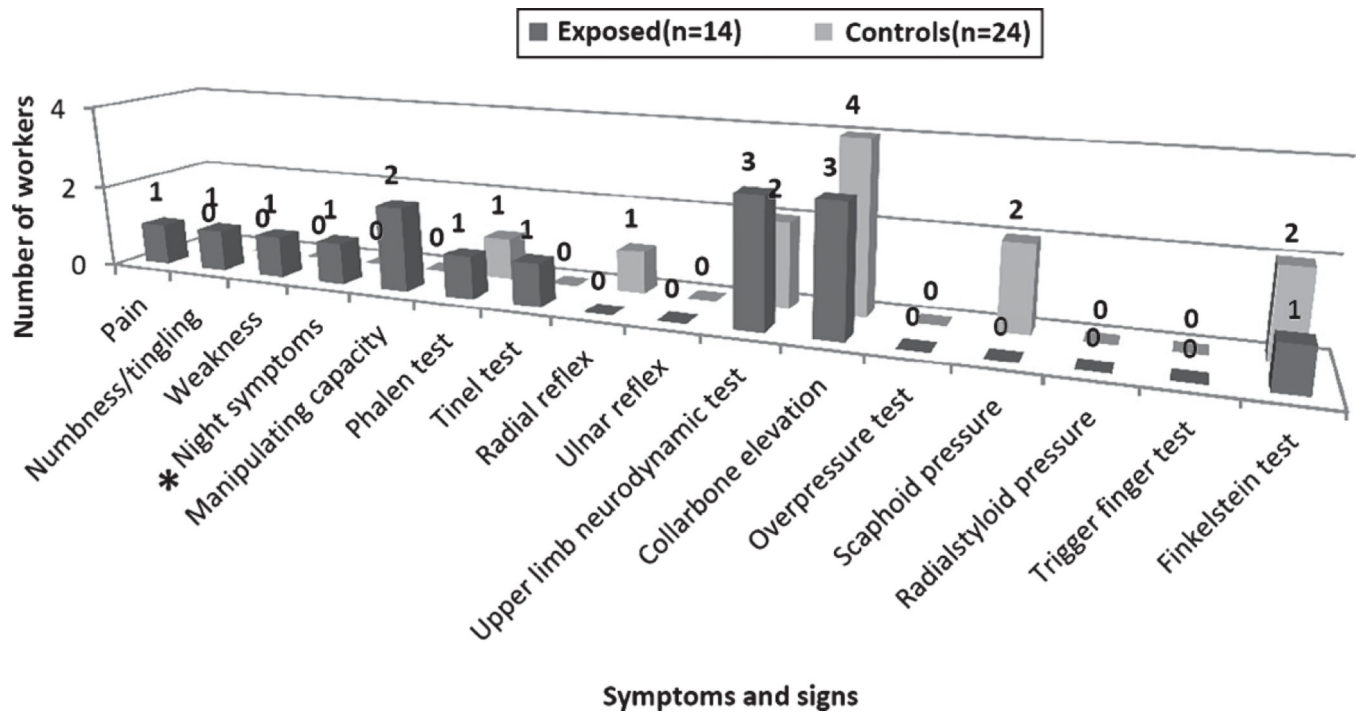


b) Rotary

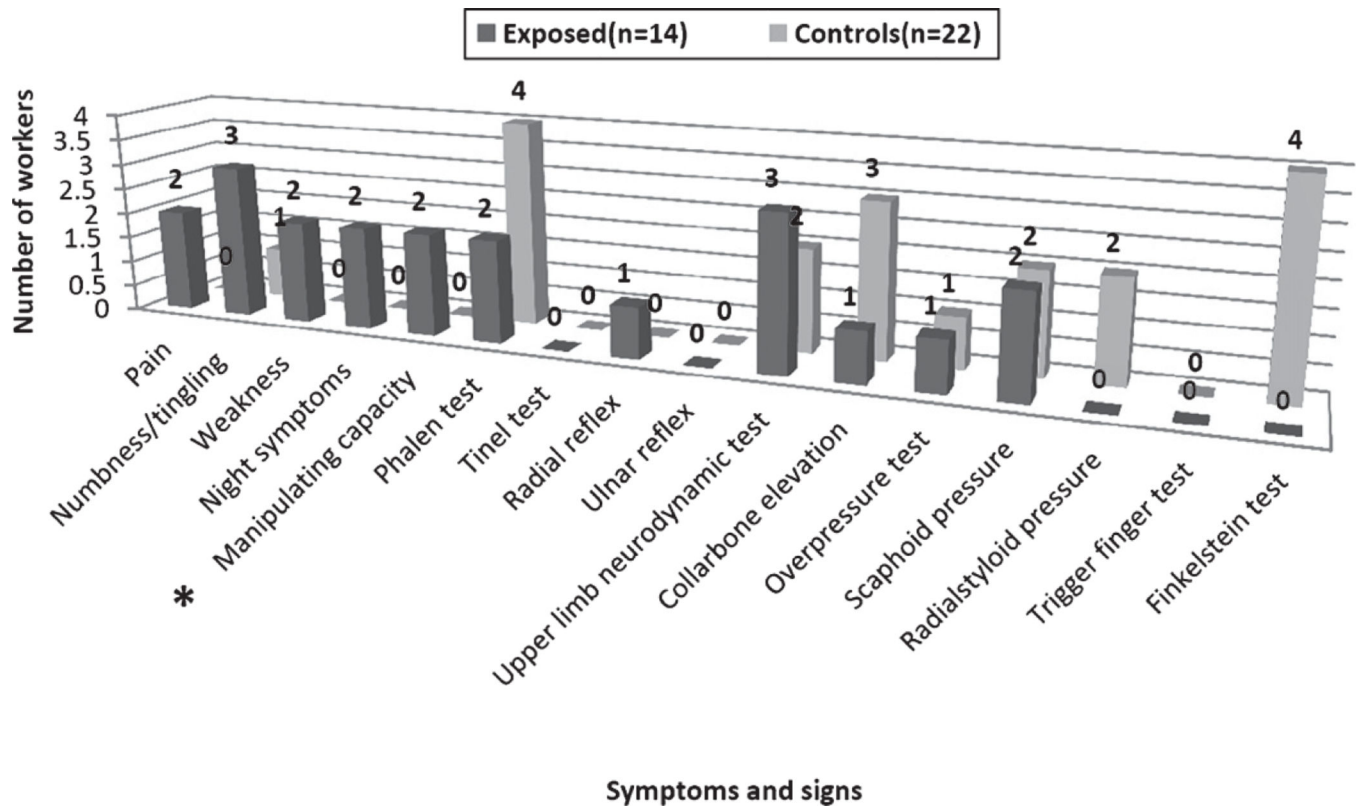


c) Parallel

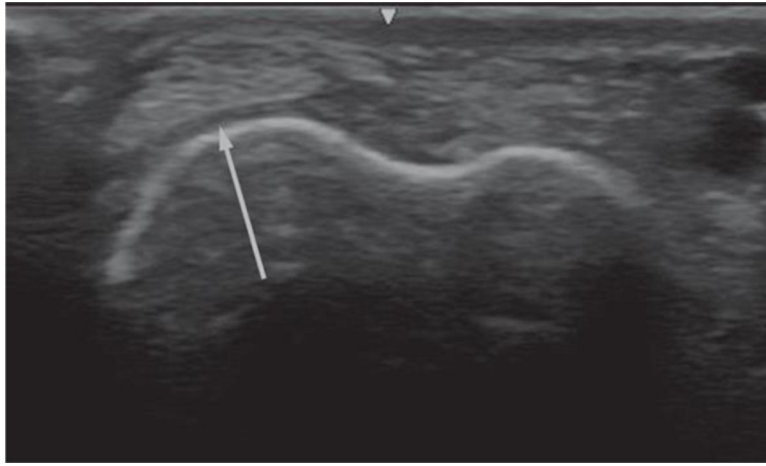
**Fig. 4.**  
(a), (b), (c). The three most common milking systems used in Italy.



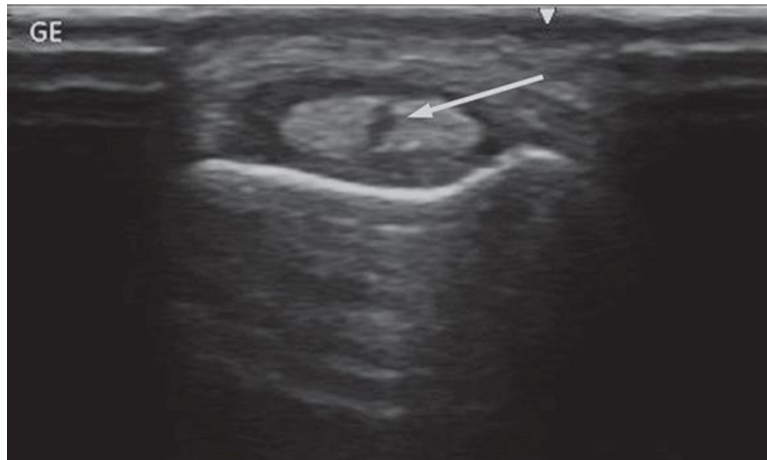
**Fig. 5.** Signs and symptoms of wrist impairment between the study groups – left hand \* $p < 0.005$ .



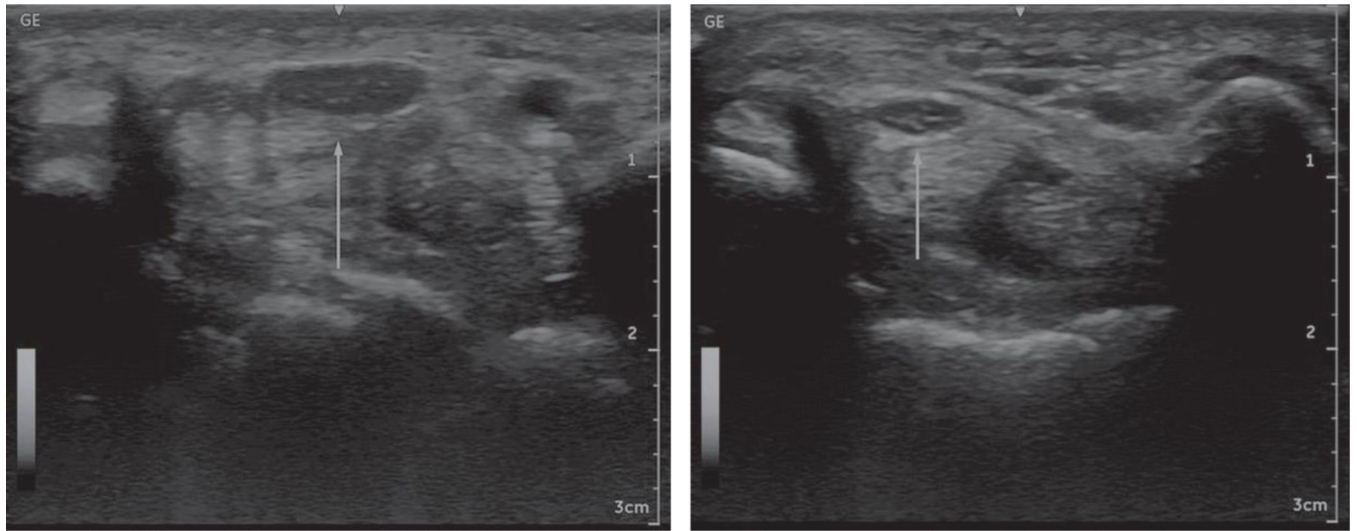
**Fig. 6.** Signs and symptoms of wrist impairment between the study groups – right hand \* $p < 0.005$ .



**Fig. 7.**  
Dislocations in the ECU tendon.



**Fig. 8.**  
Ruptures (2L) in the ECU tendon.



(a)

(b)

**Fig. 9.**  
(a) Median Nerve: increase of the transversal cross-sectional area. Exposed subject. (b)  
Median Nerve: Normal Transversal cross-sectional area.

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**Table 1**

The acoustic windows considered in the study

**US Dorsal Scans****Distal radioulnar joint**

|                 |  |
|-----------------|--|
| I compartment   | Retinaculum<br>Abductor pollicis longus tendon Extensor pollicis brevis tendon                 |
| II compartment  | Retinaculum <i>Extensor carpi radialis longus tendon Extensor carpi radialis brevis tendon</i> |
| III compartment | Retinaculum<br>Extensor pollicis longus tendon   |
| IV compartment  | Retinaculum<br>Extensor digitorum communis tendons Extensor indicis proprius tendon            |
| V compartment   | Retinaculum<br>Extensor digiti quinti proprius tendon  |
| VI compartment  | Retinaculum<br>Extensor carpi ulnaris tendon   |

**Radiocarpal/midcarpal joint****US ventral scans**

|                 |   |
|-----------------|---|
| I compartment   | Flexor carpi radialis tendon  |
| II compartment  | Retinaculum<br>Carpal tunnel<br>Median nerve<br>Flexor pollicis longus tendon<br>Flexor digitorum superficialis tendons |
| III compartment | Guyon tunnel  |
| IV compartment  | Flexor carpi ulnaris tendon   |

**Table 2**

General characteristics of the study groups

|             | Exposed ( <i>n</i> = 14) | Controls ( <i>n</i> = 24) | <i>P</i> value |
|-------------|--------------------------|---------------------------|----------------|
| males       | 14                       | 24                        | <0,05          |
| <45 yrs     | 8                        | 13                        | <0,05          |
| 45 – 60 Yrs | 5                        | 9                         | <0,05          |
| >60 yrs     | 1                        | 2                         | <0,05          |
| Italians    | 6                        | 8                         | <0,05          |
| Foreigners  | 8                        | 16                        | <0,05          |

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**Table 3**

summarizes the musculoskeletal and neurologic ultrasonography findings evidencing statistically significant differences between exposed and controls.

| Muscle skeletal and neurological ultrasonography abnormalities |                                |              |      |         |   |   |          |   |   |       |
|--|--------------------------------|--------------|------|---------|---|---|----------|---|---|-------|
| Biomechanical compartments                                     | Groups                         |              | Side | Milkers |   |   | Controls |   |   | p     |
|  | Structures                     | Compartments |      | 0       | 1 | 2 | 0        | 1 | 2 |       |
| Articulation compartment                                       | Radiocarpal & Midcarpal joints | RC & MC J    | L    | 11      | 3 | 0 | 24       | 0 | 0 | 0,020 |
|  | Radiocarpal & Midcarpal joints | RC & MC J    | R    | 8       | 6 | 0 | 22       | 2 | 0 | 0,013 |
| Extensor compartment   | Extensor carpi ulnaris tendon  | ECU          | L    | 7       | 5 | 2 | 24       | 0 | 0 | 0,000 |
|  | Extensor carpi ulnaris tendon  | ECU          | R    | 8       | 6 | 0 | 22       | 2 | 0 | 0,013 |
| Flexor compartments  | Median nerve                   | MN           | L    | 6       | 6 | 2 | 24       | 0 | 0 | 0,000 |
|  | Median nerve                   | MN           | R    | 8       | 4 | 2 | 23       | 1 | 0 | 0,003 |

Morpho-functional compartments with abnormalities. 0 = normal/expected, 1 = abnormal/unexpected, 2 = evidence of frank alteration. RC-MCJ = radiocarpal-mid carpal joints. ECU = Extensor carpi ulnaris muscle. MN = Median nerve M = Milkers. C = Controls.