

PHYSICAL WORKLOAD ON UPPER EXTREMITIES IN VARIOUS OPERATIONS DURING MACHINE MILKING

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Abstract: The aim of the study was to quantify the workload on the upper extremity for fundamental work tasks during machine milking. Eleven milkers working in a loose-housing system with a milking parlour participated in the study. Muscle activity for the biceps and the forearm flexors, as well as positions and movements of the wrists were simultaneously measured by electromyography and electrogoniometry while video-recording the work. The milking work was broken up in three main tasks “Drying (the cow’s udder)”, “Pre-milking (the first milk)” and “Attaching (the milking unit to the udder)” and three supplementary tasks. All three main tasks show high muscle load values and almost no time for rest. The highest load values for the biceps and flexor muscles were found during the tasks “Attaching, holding the milking unit” and “Drying”, respectively. For 10% of the recording time, the milkers held active hands in 42° dorsal flexion during the milking tasks “Pre-milking” and “Attaching” and in deviated positions exceeding 50% of their maximum values during “Attaching” and “Drying”. The high muscle loads in combination with extreme positions and movements of the hand and forearm might contribute to the development of injuries among milkers. The result from the study aims to form a basis for technical improvements of the milking equipment to decrease the risk for arm wrist and hand disorders.

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INTRODUCTION

Farming is a physically demanding occupation with work tasks that can cause musculoskeletal disorders and work disability [5, 23, 25, 26]. The work operations often involve lifting heavy objects, moving and carrying equipment and awkward working postures, all of which are risk factors for back injuries and other musculoskeletal disorders [4].

Dairy farming constitutes an economically important part of farming in Sweden [32], and milk production has been the object of intensive rationalisation in recent years. Despite mechanisation and automation of the jobs, several physical demanding work tasks are still to be found.

Several studies at the Division of Work Science have addressed the working environment problems in dairy barns [7, 8, 18, 19, 39, 27, 34]. Gustafsson *et al.* [9], showed high prevalence of work related musculoskeletal



Figure 1. The main milking tasks: a) “Drying (the cow’s udder)” is carried out with the active arm extended and the active hand performing work in extreme positions and with high velocities. The non-active arm and hand are unloaded. The task is defined as from the udder cloth being placed on the udder until contact between the udder cloth and the udder ceases. b) “Pre-milking (the first milk)” is, for the active side, a highly repetitive and dynamic work performed with the hand and fingers in a maximal flexed position around the cow’s teat. The task is defined as from the hand taking the first teat until the hand releases the last teat. The non-active arm and hand are unloaded. c) “Attaching (the milking unit to the udder)” means that the milker is attaching the four teat cups to the udder with the active hand, while holding the milking unit in the non-active hand. The task is defined as from the hand grasping the unit, until the hand releases the unit, after the teat-cups have been attached to the udder.

disorders in Swedish dairy farmers as compared to reference data from other occupations and females reported severe problems from the hands/wrists [37, 38].

Studies of the disorders in hands and wrists have identified the wrist positions and movements as important risk factors. Carpal tunnel syndrome and other disorders can be developed if the hand is in an extreme position during most part of the work time [1]. Pressure in the carpal tunnel has been shown to increase with increasing wrist angles [6, 42] and with increasing tension of the finger flexor tendons during muscle contraction [30]. Repetitive loaded movements are also associated with wrist symptoms [10].

To obtain generic and quantitative exposure information, direct technical measurements may be used [43]. Such measurements have been conducted for wrist positions and movements during different types of work operations [12, 14, 20, 21, 24]. These studies have shown high risk for hand disorders for work tasks involving repetitive movements.

Previous studies, using direct measurements [35, 36] showed that milking in the traditional tethering system was associated with higher peak loads for the forearm and biceps muscles than milking in the loose-housing system. On the other hand, the modern milking system implied higher “static” load than did the tethering system. Although the level of muscle activity was low during the milking work, peak loads occurred during short moments which, in combination with extreme positions and movements of the hands, might contribute to the development of injuries in the hands and wrists of milkers. Moreover, milking in the loose-housing system implied higher values of wrist flexion and deviations as well as higher velocities and repetitiveness than milking in a tethered system. These facts imply that work in the loose-housing system, which, on the other hand, also showed a considerably higher productivity, increases the risk for hand/wrist disorders.

In the two above-mentioned studies, the muscle activities and the wrist positions and movements were not

recorded simultaneously and the analysis was performed for the whole milking process. Thus, it was not possible to establish in which milking task the high loads and movements were to be found. Therefore, this present study was carried out to simultaneously measure the muscle activity of the arm, as well as the positions and movements of the wrists while video-recording the work. The aim of the study was to quantify the workload on the upper extremity for the fundamental work tasks during machine milking. The result from the study aims to form a basis for technical improvements of the milking equipment to decrease the risk for arm, wrist and hand disorders.

MATERIALS AND METHODS

The study was performed at the Dairy Research Station in Alnarp, Sweden. The Station has a loose-housing system with a herd of 170 cows and a milking parlour with 18 units, 9 on each side.

Subjects. Eleven healthy and experienced milkers (seven males, four females) participated. Their mean age was 36 years (range 24-63) and their median height and weight were 179 cm (range 158-195) and 77 kg (range 50-100), respectively. All milkers were right handed. Each milker was recorded during the milking of 63 cows in the parlour, which took about 45 minutes.

Work tasks. The milking work was divided into three main tasks “Drying”, “Pre-milking” and “Attaching” (Fig. 1) and three supplementary tasks “Between tasks”, i.e. change-over between the three main work tasks, “Between cows”, i.e. walking to the next place for the cow and “Between sides”, i.e. walking to the opposite side of the parlour, supervising the milking, waiting for the milked cows to leave, and new ones to enter the parlour. In general, the active side was the right one, i.e. the right arm and hand, but some milkers used both sides as the active one, and a few of them used, for some of the tasks, only their left side as the active one.

Table 1. Muscular load on the right and left biceps and flexor muscles during different main tasks when the right hand was the active one, as well as during the supplementary tasks. Mean values (m) and SD are shown for 11 individuals.

Muscle	Main task										Supplementary task													
	Drying				Pre-milking				Attaching		Between tasks		Between cows		Between sides									
	Right		Left		Right		Left		Right	Left	Right	Left	Right	Left	Right	Left								
	m	SD	m	SD	m	SD	m	SD	m	SD	m	SD	m	SD	m	SD								
Biceps																								
Muscular rest (% time)	0.1	0.1	6.5	5.0	0.6	0.7	16	14	0.5 ¹	0.8	0.2	0.2	6.4	6.9	6.2	7.1	3.2	4.3	3.2	3.3	33	15	38	17
Percentile (% MVE)																								
10th	3.3 ^{2,3}	1.1	0.7	0.3	1.7	0.8	0.6	0.3	2.0 ²	0.8	4.5^{2,3}	3.5	0.8	0.5	0.9	0.6	1.2	0.5	1.6	1.4	0.2	0.2	0.2	0.1
50th	9.7 ^{2,3}	3.6	1.8	1.1	5.3	2.1	1.6	0.9	5.9 ²	1.8	14^{2,3}	10	3.3	1.6	3.3	1.6	3.1	1.1	3.6	2.7	1.4	1.0	1.4	1.1
90th	20 ^{2,3}	8.0	3.7	2.1	12	5.3	4.5	2.9	14 ²	5.6	29^{2,3}	26	9.2	3.6	11	5.5	8.0	2.6	8.0	4.9	6.5	2.9	7.8	4.3
99th	33 ²	12	8.0	4.6	19	8.2	12	9.9	28 ²	15	47^{2,3}	36	19	6.8	28	15	16	5.7	20	11	18	11	27	22
Forearm flexors																								
Muscular rest (% time)	0.0	0.1	4.8	7.3	0.1	0.3	8.5	11	0.1 ¹	0.1	0.1	0.1	2.3	2.6	3.8	5.8	1.2	1.6	1.2	1.5	18	16	29	19
Percentile (% MVE)																								
10th	11^{2,3,4}	4.7	1.1	0.6	7.9 ³	4.8	0.8	0.6	6.6	3.8	6.6	3.3	2.1	1.8	1.9	2.0	2.7	1.8	1.9	1.2	0.5	0.5	0.2	0.2
50th	27^{3,4}	8.4	2.2	1.4	20	11	2.6	2.9	18	7.5	15	7.4	10	5.3	7.4	4.8	8.8	5.9	6.5	4.1	4.3	6.2	2.3	2.1
90th	50^{3,4}	17	5.4	2.9	40	20	9.7	9.6	45	17	35	16	36	15	28	13	30	22	19	7.9	24	15	16	8.6
99th	78	28	25	19	71	34	28	18	88	27	70	34	79	34	62	29	68	32	46	17	67	23	44	21

Significantly higher ($p < 0.05$; paired t-test) than: ¹“Drying”, right hand; ²“Pre-milking”, right hand; ³“Attaching”, right hand; ⁴“Attaching”, left hand. The highest values noted in the study are in bold.

Muscular load. With field equipment [2, 11], surface electromyography (EMG) was recorded (1024 Hz) bilaterally from the biceps muscles and the forearm flexors. The muscular load was normalised to the maximal voluntary EMG activity (MVE). For details on electrode placement and test contractions see paper by Stål *et al.* [36] and for recording and data processing see the paper by Hansson *et al.* [11].

The 10th (“static”), 50th (median), 90th (peak) and 99th percentiles (top peak load) of the amplitude probability distribution function (APDF; [16]) as well as muscular rest, defined as the proportion of time with an EMG activity below 0.5% MVE [15, 41], were used to describe the load.

Wrist positions and movements. Biaxial electrogoniometers (XM65, Biometrics Ltd., Cwmfelinfach, Gwent, UK) were used for recording the flexion and deviations angles of both the right and left wrists. A 12-bit data logger with a sampling frequency of 20 Hz was used [2]. After recording, the data were transferred to a PC and analysed [13].

The reference position (0 degrees of flexion and deviation) was defined as the wrist angles obtained when the subject was standing and the arms and hands were hanging relaxed alongside the body [35]. A wrist mobility test was also performed [13].

The wrist positions during work were characterised, for both dorsal-palmar flexion and radial-ulnar deviation angles, by the median position (50th percentile of the angular distribution), and the two “extreme” positions (10th and 90th percentiles).

For describing movements, the angular velocity was calculated, and the 50th and 90th percentiles of the velocity distribution were used. Moreover, a velocity below 1 °/s for a continuous period of at least 0.5 s was selected to characterise when the hand was held still.

Video recording and analysis. Video recordings, using a handheld camcorder, with an integrated clock that stamped the video frames with a resolution of 0.1 s, were performed simultaneously with the EMG and goniometer recordings. The starting of the EMG and goniometer recordings, according to a “master clock”, were recorded and the “master clock” was video taped at the beginning of the registration for each milker; hence the video recordings could be synchronised to the EMG and goniometer registrations. From the video recordings, the start and stop times for each occurrence of the individual task, as well as which side was the active one, were noted in data files. These files were used as input to the computer programme for analysing the EMG and goniometer registrations, as well as for determining the number of occurrences and the time consumption for the work tasks.

Table 2. Wrist positions and movements (velocities, percentile values in °/s and velocities below 1°/s, in % time), for both flexion and deviation, and for both right and left hand during the main milking tasks when the right hand was the active one, as well as during the supplementary tasks. Mean values (m) and SD are shown for 11 individuals.

	Main task								Supplementary task															
	Drying		Pre-milking		Attaching		Between tasks		Between cows		Between sides													
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left												
	m	SD	m	SD	m	SD	m	SD	m	SD	m	SD												
Positions* (percentile°)																								
Flexion																								
10th	-39	9	-27	12	-42	5	-27	14	-42	6	-35	12	-36	7	-36	9	-35	9	-29	9	-30	10	-25	11
50th	-16	11	-9	11	-24 ^{3,4}	7	-8	8	-15	5	-14	11	-9	6	-10	7	-8	9	-5	11	-3	5	-3	5
90th	11 ²	16	9	7	-3	10	10	7	21 ^{1,2,4}	6	12 ²	10	15	9	14	6	22	12	17	12	17	7	13	10
Deviation																								
10th	-15 ²	7	-8	6	-11	4	-9	5	-12	5	-12	7	-11	4	-13	5	-11	5	-11	4	-9	5	-10	3
50th	-4	8	0	6	-3	5	-0	4	2 ^{1,2}	4	3	9	1	4	0	4	1	4	0	3	1	3	1	2
90th	7	7	9	3	7	6	9	4	15 ^{1,2}	416 ^{1,2}	8	13	4	11	5	12	4	11	3	11	3	8	4	
Movements																								
Velocity ≤ 1°/s (% time)																								
Flexion	0.0	0.0	0.2	0.6	0.0	0.0	1.0	1.7	0.0	0.0	0.0	0.0	0.2	0.5	0.2	0.7	0.1	0.3	0.1	0.2	1.2	1.9	1.9	3.6
Deviation	0.0	0.1	1.1	1.9	0.0	0.0	5.3	6.1	0.0	0.0	0.0	0.0	0.5	0.7	0.6	1.4	0.3	0.5	0.5	0.6	2.9	3.5	3.2	4.3
Velocity (percentile °/s)																								
Flexion																								
50th	69 ⁴	15	11	13	59 ⁴	10	11	14	62 ⁴	13	20	3.4	44	16	29	12	46	7.5	28	12	18	7.8	13	4.5
90th	197 ^{2,4}	42	52	36	154 ⁴	19	81	57	219 ^{2,4}	33	103	20	173	40	129	22	166	18	118	25	101	21	81	15
Deviation																								
50th	31 ^{2,4}	5.9	6.6	9.2	24 ⁴	3.4	5.2	6.6	30 ^{2,4}	4.9	12	3.0	20	6.0	15	7.1	22	3.9	13	6.3	8.0	3.5	6.2	2.5
90th	89 ^{2,4}	14	30	26	70 ⁴	11	35	23	102 ^{1,2,4}	12	55	8.1	75	11	64	16	77	11	57	14	46	9.3	39	11

*Positive values denote flexion in palmar direction and deviation in ulnar direction. Significantly higher ($p < 0.05$; paired t-test) than: ¹“Drying”, right hand; ²“Pre-milking”, right hand; ³“Attaching”, right hand; ⁴“Attaching”, left hand. The highest values noted in the study are in bold.

RESULTS

Muscular load. Table 1 shows the muscular load on the biceps and the forearm flexor muscles for the main tasks when the right hand was the active one, as well as the supplementary work tasks, for the 11 individuals. When the left hand was the active one, the percentile values differed somewhat in magnitude but otherwise were analogous to the values for the right active side. Fewer milkers used their left hand as the active one, and when they did so they used it less frequently (Tab. 3). Hence, the right side values, when the right hand was the active one, are representative for the active side and, for simplicity, right side is used below synonymously with the active side.

The flexor muscle load was up to about four times higher than the load on the biceps muscle.

The work tasks “Drying”, “Pre-milking” and “Attaching” showed, as expected, high loads on the right side muscles, and for “Attaching” also on the left side.

The “static” and the median loads were particularly high on the flexor muscles during all of the three main milking tasks, with the highest value (significantly higher than “Attaching”, both right and left hand) during the task “Drying”, 11% MVE and 27% MVE, respectively on the right hand when this hand was the active one. The highest value for the peak load, significantly higher than “Attaching”, both right and left hand, was found for the task “Drying” (50% MVE). The top peak load was highest (n.s.) for “Attaching”, right hand (88% MVE).

The highest values (significantly higher than “Pre-milking” and “Attaching”, right hand) for the “static” and median load for the biceps muscle were found for the milking task “Attaching”, left (i.e. holding the milking unit with the left hand) (4.5% MVE and 14% MVE, respectively). Also, the significantly highest peak and top peak values were found for the same task (29% MVE and 47% MVE, respectively). The muscular rest for all milking tasks was higher for the biceps compared with the flexor muscles. For all main milking tasks the muscular

Table 3. The number of identified occurrences of the main milking tasks (separated on both right and left active hand) and of the supplementary tasks and their durations (mean (m), SD and range) are shown for 11 individuals. The number of individuals performing the various tasks and the relative duration of the tasks are also shown.

Task	Active hand	Occurrences	Individuals	Duration (s)			Relative duration ^a (% time)
				m	SD	range	
Main task							
Drying	right	473	10	5.1	2.6	2.0-10.8	12
Drying	left	69	5	5.8	3.2	3.1-10.8	
Pre-milking	right	374	8	6.3	1.8	3.4-8.6	14
Pre-milking	left	167	6	6.2	1.3	4.4-8.3	
Attaching	right	208	11	11.4	2.8	7.9-17.0	25
Attaching	left	72	6	11.8	3.0	8.0-15.0	
Supplementary task^b							
Between tasks		1034	11	1.9	0.7	1.0-2.9	8
Between cows		484	11	5.2	2.4	3.1-10.3	10
Between sides		47	11	145.6	64.7	56.7-249.8	31

^a The relative duration was calculated from the mean duration of each task (for “Drying”, “Pre-milking” and “Attaching” weighted according to the mean duration and relative number of occurrences when the right and left hand was the active one) and the actual number of occurrences during milking of 63 cows (63, 63, 63, 126, 56, 6 for “Drying”, “Pre-milking”, “Attaching”, “Between tasks”, “Between cows” and “Between sides”, respectively). ^b not relevant to separate by hand.

rest for both biceps and flexors were low (between 0.0–0.6% time), i.e. the right biceps and flexors for “Drying” and “Pre-milking” and both right and left for “Attaching” showed almost no time for rest.

During “Drying” and “Pre-milking” the left side muscles showed a low load with a muscular rest ranging from 4.8% to 16% of the time, although with a large inter-individual variation.

Regarding the supplementary tasks, the load was quite symmetrical regarding the right and left sides for the biceps muscles, while the load on the flexor muscles was higher for the right side compared to the left side. As for the main “high-load tasks” the load on the forearm muscles was higher than on the biceps muscles. “Between sides” showed the lowest loads; the biceps muscles had a median load of only 1.4% MVE and rested for about a third of the time, and the flexors had median loads of 4.3% and 2.3% MVE and muscular rest for 18% and 29% of the time, for the right and left sides, respectively. These values are for the left sides similar to the load for the non-active side during “Drying” and “Pre-milking”. The load for the tasks “Between tasks” and “Between cows” was higher than for “Between sides”, but still considerably below the loads for the “high-load tasks”.

Goniometry. The flexion mobility for the eleven subjects was 133°; 63° dorsal flexion and 70° palmar flexion for the right hand, and 135°; 63° and 72°, respectively for the left hand. The average deviation mobility was 53°; 25° in the radial and 28° in the ulnar direction for the right hand and 53°; 22° and 31°, respectively for the left hand.

The percentile values for the positions and movements when the left hand was the active one were in magnitude somewhat different but otherwise analogous to the values when the right hand was the active one. Hence, with the same reasoning as for the muscular load, the values when the right hand was the active one are presented, and the right side is used synonymously with the active side.

Table 2 shows wrist positions and movements, for both flexion and deviation, and for both hands during the main milking tasks when the right hand was the active one, as well as for the supplementary tasks.

The wrist was held in the most dorsiflexed position during the milking task “Pre-milking” concerning the median value (-24°), significantly higher ($p < 0.05$) than the median values for “Attaching”, right and left hand (Tab. 2). For the 10th percentiles the most dorsiflexed positions (n.s.) were during the tasks “Attaching”, right hand (-42°) and “Pre-milking” (-42°). The wrist was held in the most ulnar deviated position during the task “Attaching”, both right (15°) and left (16°) hand compared with the other two milking tasks ($p < 0.05$). This is true (n.s.) also for the other percentiles.

The highest median velocities both for flexion and deviation were found for the task “Drying” (69°/s and 31°/s, respectively), significantly higher ($p < 0.05$) than “Attaching”, left hand. The highest peak velocities for flexion and deviation were found for the task “Attaching”, right hand (90th percentile; 219°/s and 102°/s, respectively), significantly higher ($p < 0.05$) than almost all the other tasks.

None of the main milking tasks included any rest for the active hand, i.e. for all tasks the wrist was in motion more than 1°/s during the measured time period.

The left hand during “Drying” and “Pre-milking” showed both moderate dorsiflexed positions (i.e. -27° and -27° , respectively) and ulnar deviated positions (i.e. 9° and 9° , respectively). Also, the velocities for the left hand were much lower (up to six times lower) than for the right hand.

During the supplementary tasks, the left hand was in about the same positions as for the tasks “Drying” and “Pre-milking” except for the task “Between tasks” where the left hand was in -36° dorsiflexed position which was the same value as for the right hand. The velocity values were also lower for left hand compared to the right hand for all the supplementary tasks.

Video analysis. Table 3 presents the number of occurrences and the duration of the main and supplementary tasks that could be identified from the video recordings. The calculated relative duration of the milking time for the different tasks is also shown.

The measured times for “Drying”, “Pre-milking” and “Attaching” were 5.1, 6.3 and 11.4 s, respectively when the right hand was the active one and similar when the left hand was the active one. The supplementary tasks constituted half of the working time.

DISCUSSION

This study showed high muscle loads during all three main tasks on the active side and also for “Attaching” for the non-active side. For the supplementary tasks, the task “Between sides” showed both the lowest load and the highest muscular rest. Both the highest “static” and median muscle loads on the flexor muscles were found for the “Drying” task and the highest peak load during the “Attaching” task, right hand (i.e. attaching the teat cups). The highest values on the biceps muscle were found for the “Attaching” task, left hand (i.e. holding the milking unit). The high muscle loads in combination with extreme positions and movements of the hand and forearm might contribute to the development of injuries among milkers.

For comparing the load for the complete milking process with previous studies, this load was derived by: (1) analysing the complete recording as one task, as well as (2) calculating the time-weighted load, based on the load for each task and their relative duration (data not shown). For some exposure parameters (e.g. mean values and fractions of time) the time-weighted values are, by definition, identical to those obtained by analysing the corresponding recording. However, for other parameters (e.g. percentiles of the amplitude distribution), the time-weighted values are approximations. For the 10th, 50th and 90th percentiles of the angular distributions, the 50th and 90th percentiles of the angular velocity distributions, and the 50th, 90th and 99th percentiles of the muscular load the error of this approximation is reasonable. However, for the 10th percentile of the muscular load, the time-weighted values overestimated the actual load by as much as a factor of 4.0 (range 3.5 – 4.7) for the four muscles.

The EMG-values from the biceps and flexor muscles correspond very well to the values found in an earlier study of milking in a loose housing system [36]. The values from the flexor muscles are close to the values found in deboning of poultries [17] and somewhat higher than the values found in dentist work [44].

Several wrist surveys have shown that there is a correlation between the hand positions and the perceived disorders in wrists and hands [1, 29, 33]. Wrist positions in about 45° dorsal flexion and extreme deviated positions, especially ulnar deviated positions, increase the risk for developing injuries. In this study, the milkers held right hands at 42° for 10% of the recording time for the milking tasks “Pre-milking” and “Attaching”. Moreover, both hands were more than 12° radial and 15° ulnar deviated for 10% of the recording time in the milking task “Attaching”. The radial and ulnar deviation for “Attaching”, left hand (i.e. holding the milking unit in the left hand) were 12° and 16° , respectively which is about 10° and 15° from their maximum values of 22° radial and 31° ulnar deviation. The highest value of radial deviation was found for the “Drying” task - right hand, which is about 68% of their maximum value. The risk of developing injuries in wrists and hands increases when the angle of deviation exceeds 50% of the maximum value [33]. There is also an increased risk of developing carpal tunnel syndrome (CTS) when working with the wrist in a non-neutral position [31].

As for the muscle load values, the position and velocity values for the whole milking process were similar to the values found in the earlier milking study of wrist positions and movements [35].

For all three main milking tasks the registered velocities were higher than those values described in repetitive work with high risk of elbow and hand disorders in the fish-processing industry [24] and giro-form data entry work [22].

The registered times for the different tasks may be important data for assessing the effect on the time consumption and productivity (cows milked per hour) of the mechanisation or automation of one or several milking tasks, and for an evaluation of physical exposure and risk of developing musculoskeletal disorders in milking [28].

The milking capacity for the studied milkers was about 63 cows/45 minutes. The registered times for the main milking tasks were together about 23 s/cow which means that for more than half of the time in the parlour (51%), the milkers were exposed to high hand and forearm muscle loads, extreme wrist positions and high wrist velocities.

It was only during the supplementary task “Between sides” the milkers had sufficient time (about 31% of the milking time) for muscular rest of both the right and left hands. It may be a temptation of rationalising motive to reduce the time for “Between sides”, but this rest time is necessary for the muscles to recover from the high loads during the main work tasks and to prevent musculoskeletal disorders. Hence, a better strategy is to

reduce the time for exposure to high loads and the extreme positions during the main milking tasks.

During the "Attaching" task, with the left hand (i.e. holding the milking unit), the cluster is kept in the palm of the hand with the wrist loaded statically in a dorsiflexed position, the arm almost extended and the forearm maximally supinated. This position combined with high muscle loads around the elbow can generate nerve compressions followed by injuries and pain in the hands and wrists [36]. For reducing the load during the "Attaching" milking task a weight-reducing device has been developed in co-operation with deLaval International AB [40].

This study has shown high load and movement values also for the "Drying the cows udder" and "Pre-milking" tasks. Thus, development of new techniques for facilitating these tasks is necessary for reducing the injuries in hands and wrists. A new study is therefore in progress at the Division of Work Science for developing ergonomic improvements such as technical aids for these milking tasks.

A new in-depth study will also follow this one for analysing where in the three main tasks the peak values appear, by analysing the shape of the EMG and goniometer curves for each individual task simultaneously with the video recordings.

CONCLUSIONS

All three main milking tasks during machine milking (i.e. "Drying the cow's udder", "Pre-milking the first milk" and "Attaching the milking unit to the udder") showed high muscle load values and almost no time for rest.

The highest load values for the biceps and flexor muscles were found during the tasks "Attaching, holding the milking unit" and "Drying", respectively.

Extreme wrist positions in dorsal flexion were found during the milking tasks "Pre-milking" and "Attaching". "Drying" and "Attaching" showed high values in deviation.

The highest median and peak velocities both for flexion and deviation were found for the tasks "Drying" and "Attaching the teat cups to the udder", respectively.

The three "high-load tasks" constituted half of the working time. In only 31% of the milking time did the milkers have sufficient time for muscular rest of both the right and left hands.

The high muscle loads in combination with extreme positions and movements of the hand and forearm might contribute to the development of injuries among milkers.

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