The Influence of Varying Working Heights and Weights of Milking Units on the Body Posture of Female Milking Parlour Operatives

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ABSTRACT

Workers in modern German milking parlours – especially women – were found to be overrepresented in those suffering from musculoskeletal disorders [MSD]. The number of cases was compared to the whole employed population. The objective of this study was therefore to assess the effects of workstation geometry on female milking parlour operatives. Motion analysis in combination with Electromyography [EMG] data recording was applied to evaluate three different working heights and two weights of milking units. Results showed that especially the weight of the milking unit strongly influenced the workload. The optimal working height for attaching the cluster was found to have the teat ends at shoulder level of the parlour operative.

Keywords: Musculoskeletal disorders, motion analysis, body posture, work load assessment**,** Germany

1. INTRODUCTION

The work situation in dairy farming has changed over the past decades due to process mechanisation and automation going along with increasing herd sizes. Awkward working postures and physically demanding work tasks like lifting and carrying buckets full of milk, characteristics of traditional tie stall systems, have nearly disappeared, but at the same time the variety of tasks has decreased with the change in systems. The number of cows milked per hour has increased rapidly from approximately 40 to 100 cows with automation and conversion of production. According to a Finnish study the utilization rate of a milker is over 90 % in herringbone and auto tandem parlors, when there are eight or more milking units, one milker and more than 40 cows (Tuure & Alasuutari, 2009). This means that there is not much time for muscle rest during milking. In herringbone systems the utilization rates are slightly higher than in auto tandem systems of similar sizes. The expectations on the worker's performance are still increasing due to ongoing mechanisation as well as the fierce competition for costs.
Currently, it appears that the reduction of risk factors for back injuries, namely carrying heavy loads and awkward postures have obviously reduced the dynamic physical workload of milking cows. This is contradictory to constant or even rising rates of work absenteeism as a symptom of

increasing discomfort, which was found in several recent studies. The evaluation of temporary disability data in Germany has shown a significant rate of work absenteeism for female milking parlour operatives in comparison to the whole employed German population. Diagnosis related to disorders of the upper limb like enthesiopathies, shoulder lesions and carpal tunnel syndrome, but also disorders of the lower back (dorsalgia) and of lower limbs (knee osteoarthritis and meniscopathia) were the most prevalent (Liebers & Caffier, 2006).

A Swedish long term survey also reported increased discomfort among milkers (Pinzke, 2003), associated with the change in systems. The Swedish studies showed that milking in the traditional tie stall system was associated with higher load peaks for the forearm and biceps muscles, but modern milking systems have a higher static load, higher values for wrist flexion as well as higher rapidness and repetitiveness (Stal *et a*l,. 1999; Stal *et al*., 2000).

Finally almost one out of three Finnish milk producers who had a new loose housing barn had experienced symptoms in neck-shoulder region often or almost all the time (Tuure & Karttunen, 2007).

The specific aim of our study was therefore to precisely analyse the ergonomic situation in modern milking parlours and to quantify the impact of different working heights as well as weights of milking units. Milking units available on the market weigh from approximately 1.4 kg to up to 3.5 kg. The work height geometry in milking parlours is influenced by several factors. It depends on the individual body height of the worker and the varying positions of the cow's udders as well as on the parlour construction. The depth of the pit is mostly fixed and has to suit all employees ranging from about 160 to 190 cm body height. Nevertheless, if it was possible to change the depth of the pit floor, the height may have to suit more than one worker at the same time. A thorough literature review has revealed no guideline on how to adjust the proper floor height; therefore another prospective outcome of the study was to give advice to farmers how to best adapt the equipment to the worker's needs. If the work height is too high, the worker may be forced to abduct the upper arm. If on the other hand the work height is too low, this may force the worker to forward flex the back and/or head. Arm abduction, pronounced forward flexion of the back and extreme wrist positions are risk factors for work related muscular skeletal disorders.

The force on the forearm, which has to hold the unit beneath the udder, can vary extremely while the cups are attached one by one. The force depends on the weight of the unit and at the same time on the body posture. The theoretical moments of torque based on the measured length of lever arm, which were observed while attaching a milking unit, ranged from 4.5 for a light to nearly 9 Nm for a heavy milking cluster (Jakob *et al.*, 2007). Both the weight and the body posture strongly influence work performance, muscular strength and endurance. Although in general there are fewer poor working postures in parlor milking than in tie stall milking, more postures with upper limbs above shoulder level appear in parlor milking according to a Finnish study. In large loose housing systems the amount of these postures was 15 % of the total daily working hours (Tuure & Alasuutari, 2009).

Motion analysis in combination with Electromyography [EMG] data recording (Liebers *et al*., 2009) was chosen to estimate the physical load of three different working heights and two weights of milking units.

2. METHODS

2.1 Test procedure

The study was performed in a laboratory setting (see figure 1) using an artificial udder to be able to control and adjust different working heights. Wooden platforms were used to change the floor height. For each person the udder height at teat ends was individually adjusted 15 cm above, at and 15 cm below shoulder level (see table 1).

The milking parlour design was identical to a 30° herringbone parlour. Vacuum was also available to keep the teat cups attached to the artificial udder. Apart from the working heights two different milking units were tested. The light one weighed 1.4 kg and the heavy one 2.4 kg. The six settings (3 heights x 2 weights) were repeated 15 times each. Duration per repetition was fixed to one minute assuming an hourly rate of 60 cows. Within the duration of one repetition the worker had to attach the milking cluster and take it off after half a minute. The time in between two cycles was free to recover. The process of attaching the cluster included the work elements grabbing the milking unit with the left hand and holding it beneath the udder while the right hand was attaching cup by cup to the teats.

Table 1: Experimental matrix

	above shoulder level	at shoulder level	below shoulder level
Light cluster	A1	B1	C1
Heavy cluster	A2	B2	C2

2.2 Subjects

Six experienced, professional female milkers were included in the measurements. The body height of the test persons ranged from 157 cm to 176 cm, their age from 25 to 39 years and their body mass index from 19 to 31.

The project was approved by the Ethics Committee of the Charité-University of Medicine Berlin and all subjects signed informed consent forms and voluntarily participated in the data collection.

2.3 Body posture analysis

Body postures can be assessed in different ways by direct technical measurements, observations and semi-technical measurements. Observational techniques always depend on the angle from which the observer sees the body part as well as the observer's ability to judge the different angles.

In order to quantitatively determine the body posture characteristics, 3D motion capture was used. Specifically, two Canon XM 2 cameras gathered kinematic data from the subjects. Capture occurred at a rate of 50 frames/second and was rendered in three-dimensional computer space with SIMI Motion® (Unterschleißheim, Germany) software. Calibration was carried out with a 14 point system covering the area of activity.

Each subject wore black garment with tight fit, covering the area of marker application.

The markers were attached to the top of the clothes, using eight positions (see figure 1). Three markers were fixed along the spine (C7, Th12, S1), one on the back of the head, one on the acromion, one on the trochandor major, one on the epicondylus and one on the wrist.

The evaluation of the body postures was done according to different workload assessment tools such as DIN EN 1005-4, ISO 11226 and RULA (McAtamney & Corlett, 1993). Four variables were calculated, respectively the thorax inclination, side bending, torsion and the upper arm elevation.

Figure 1: Experimental setting working height above shoulder level using the light milking unit (photo in the middle) showing the marker positions

2.4 Statistical analysis

Ex ante estimation of study size was made considering the used experimental study design and the statistical method. The estimation indicated that strong effects could be detectable with the used design and number of test persons.

Variables were averaged for every ergonomic variation/setting. Description and intraindividual comparisons were made for the different experimental situations/settings using a general linear model for repeated measurements (GLM-RM, software SPSS 15). GLM-RM was performed for each outcome considering the factors "working height" and "weight of the milking unit". If necessary, confounders (age, body-mass-index, body height or arm length) were included in the models. The sequence of the six experimental settings was systematically changed for each subject to avoid sequence effects.

3. RESULTS

For the evaluation of the outcome several assessment criteria were defined to rate the workload: Self evaluation of perceived exertion, duration of muscular activity, trunk inclination, upper arm elevation, side bending and torsion, heart frequency and the integrated EMG of 14 muscle groups. In this article only the body postural parameters will be presented.

3.1 Body posture analysis

RULA, ISO 11226 and DIN EN 1005-4 criteria of work load assessment were applied to describe the body posture. Parameters such as trunk inclination, head inclination and upper arm elevation were calculated. For this, the relevant body segments were equipped with markers (see figure 1). The planes of the reference system were also used for the determination of specific angles, respectively upper body inclination and side bending of the torso.

In accordance to ISO 11226 torsion and side-bending were only considered if the measured values exceeded 10° in either direction.

A significant influence of the weight of the milking unit was given for the torsion. While side-bending showed large variation, weight and working height were not statistically significant (see figure 2).

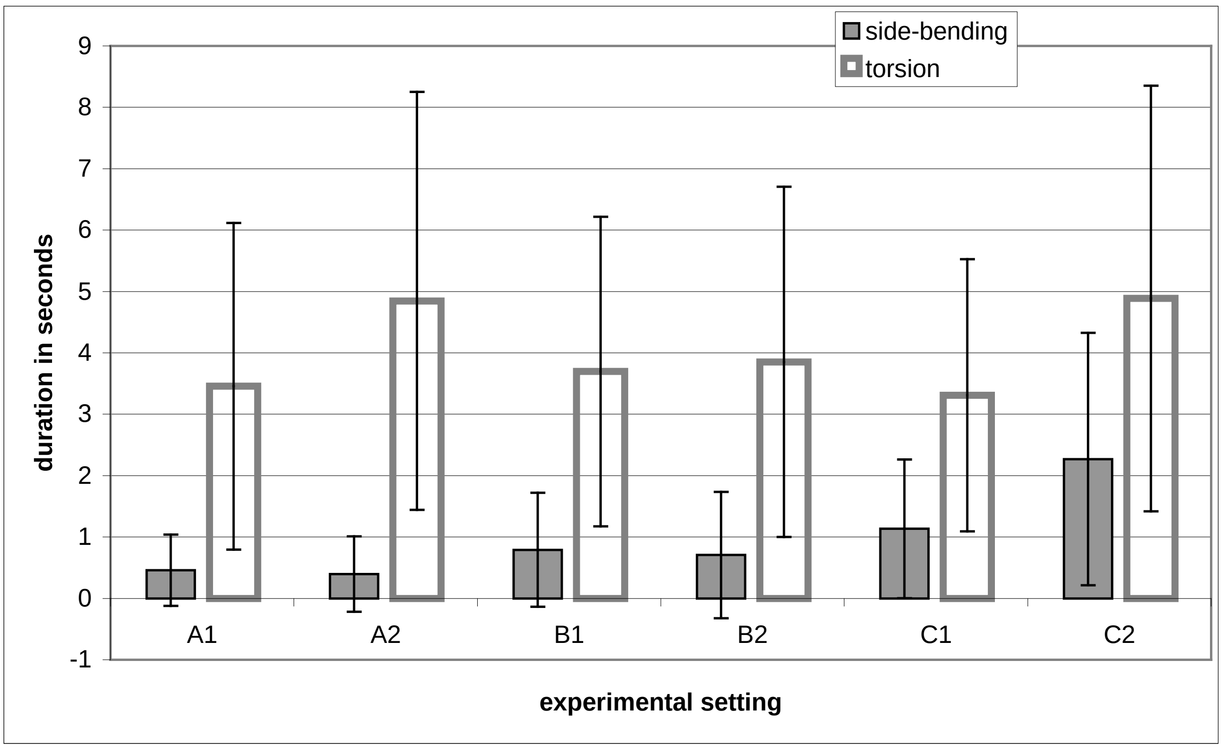

Figure 2: Average time in seconds and standard deviation when torsion and side-bending of the trunk exceed 10° while once attaching the teat cups (see table 1)

Trunk inclination and upper arm elevation were strongly influenced by the working height (see figures 3, 4 and 5). Only the upper arm elevation of the left side was taken into consideration. The left arm was holding the milking unit at a constant distance to the udder, which can be considered a static working posture if it takes longer than four seconds for each cycle. Within the experimental setting each holding time was followed by a recovery time, one minute per cycle altogether.

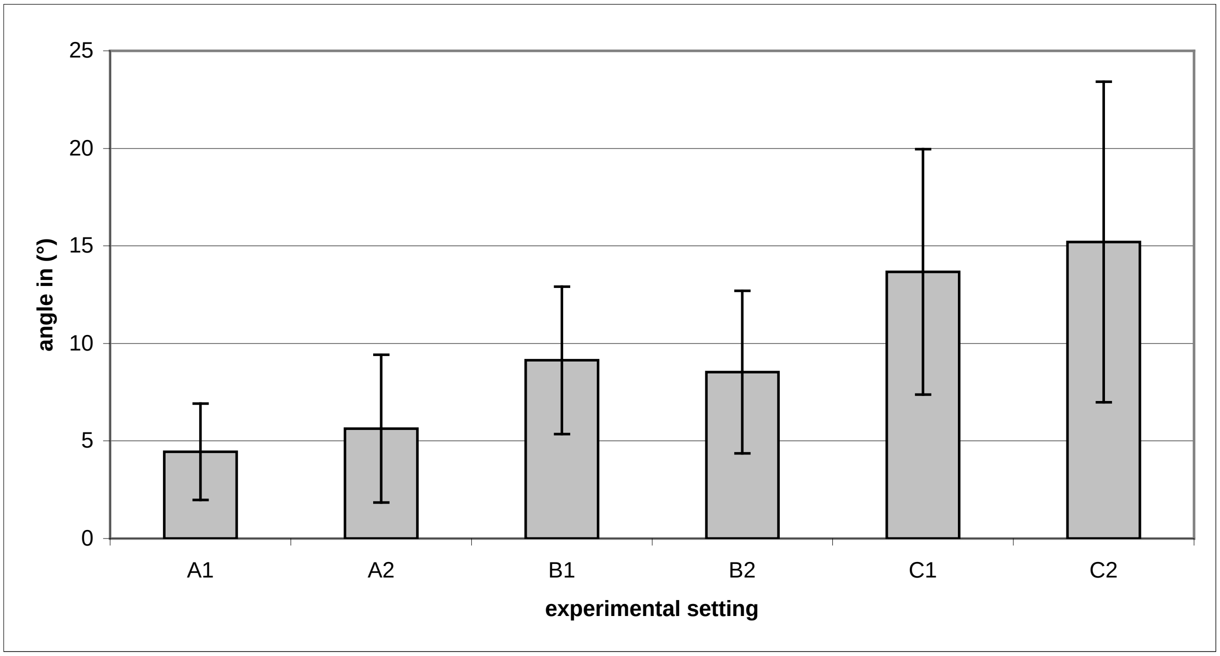

Figure 3: Average trunk inclination and standard deviation for the different experimental settings (see table 1)

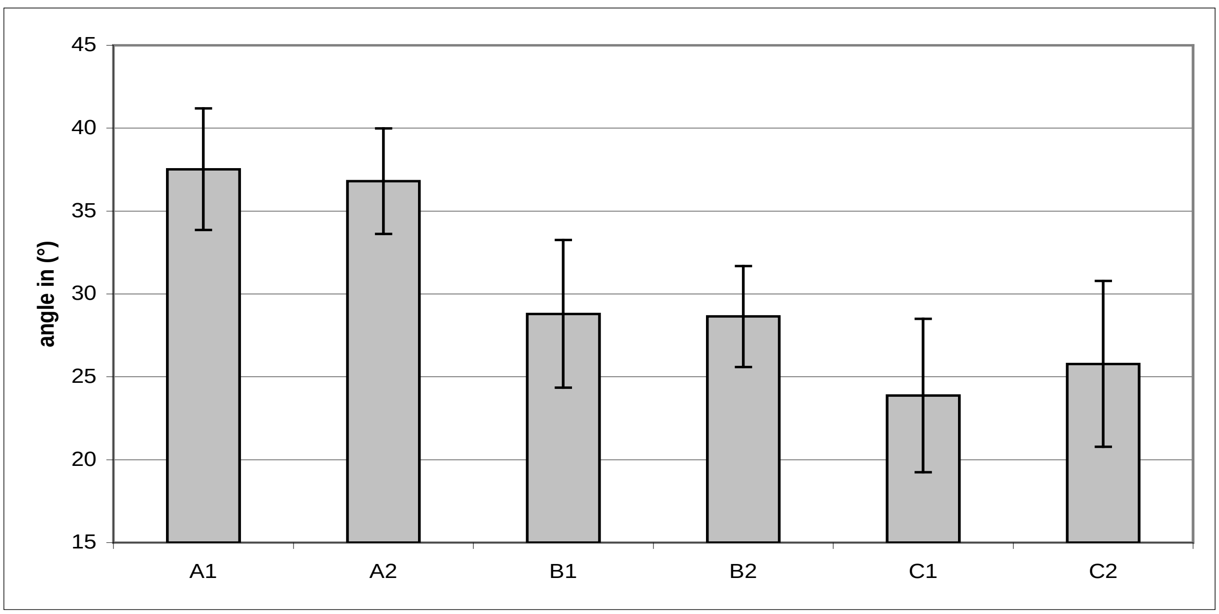

Figure 4: Average upper arm elevation and standard deviation for the different experimental settings (see table 1)

The body kinematics followed the expected patterns. If the udder was adjusted above shoulder level, the upper arm elevation showed the highest values (see figure 4) whereas the udder below shoulder level induced the highest values for the trunk inclination (see figure 3). The interpersonal differences were fairly large, but all participants showed the described trend.

Figure 5 displays the percentage of upper arm elevation for different ranges and the different experimental settings.

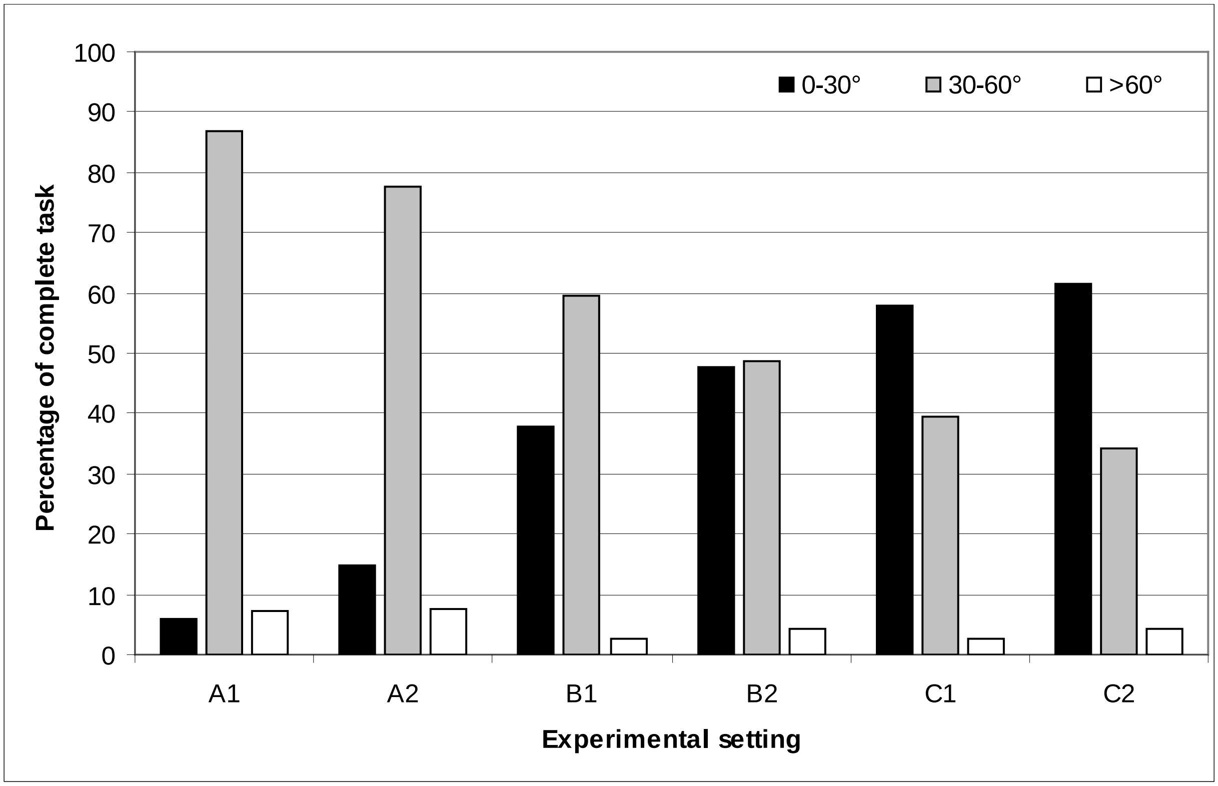

Figure 5: Percentage of upper arm elevation for different ranges, average over all test persons

Classification was harmonised with a Finnish study group (Tuure & Alasuutari, 2009) using VIRA (Persson & Kilbom, 1983) for measuring the upper arm flexion. Similar to the average upper arm elevation the percentage of flexion between 30°and 60° decreased with a decrease of the working height. Very rare flexion above 60° was measured. In comparison to our results the Finnish group found a percentage of 84 for left upper arm flexion below 30°, 9 % of the time the flexion was between 30° and 60° and 8% of the time above 60% during attaching the cluster. They did not differentiate the working height as they were obtaining their results in a field study.
Our results differed from the Finnish study as shown in figure 5. The overall percentage for the class 0-30° was 38, for 30-60° it was 58 and a rest of 5% for the elevation above 60°.

4. DISCUSSION

As expected, working with a heavier milking unit was associated with higher physical and perceived exertion. According to the rating of perceived exertion subjects preferred working with a light milking unit at shoulder level. The analysis of the muscular exertion underlined this fact. On the other side, using heavy milking units and working above or below shoulder level significantly increased muscular exertion. Ergonomic recommendations and milking machine design need to take these facts into consideration. Milking units weighing about 2,4 kg are very common in practice, because the milk is thought to be released more completely and faster through an increased weight on the teats. At the same time worker comfort declines the heavier the milking clusters are. The difference of one kilogram in the experimental setting had a significant influence on several of the assessment criteria.

The work load assessment based on the body posture depends on the standards applied. The average trunk inclination for all test persons was within the acceptable range according to all applied standards named (RULA, DIN and ISO). One test person exceeded the acceptable range of 20° for trunk inclination when working below shoulder level.

The upper arm elevation did not exceed 45° on average for all test persons, which is a limit within RULA classification. DIN ISO 11226 requires the evaluator to consider the holding time, if the upper arm elevation exceeds 20° without full arm support. This was the case with all experimental settings. Regarding figure 5 the upper arm elevation is above 20° for at least a third of the time up to nearly all the time In addition to that, a weight is held while lifting the arm with the moment of torque increasing due to the weight and upper arm elevation. The impact of the weight was clearly reflected in the increase of the subjective perceived exertion as well as the increased muscular activity (Liebers *et al.*, 2009). Attaching a milking unit requires approximately 10-15% of the maximum voluntary muscular contraction on average (Liebers *et al*., 2009).

Due to the anticyclical movement of the upper arm elevation and trunk inclination when varying the working height, it was not possible to determine the best ergonomic setting by solely regarding the body posture. In consequence more criteria were included. For the final evaluation the average values for all assessment criteria were put into a score chart and the overall average was calculated (see fig. 5) disregarding any severity of a single parameter. The lowest value always scored with 1 and the highest with 6.

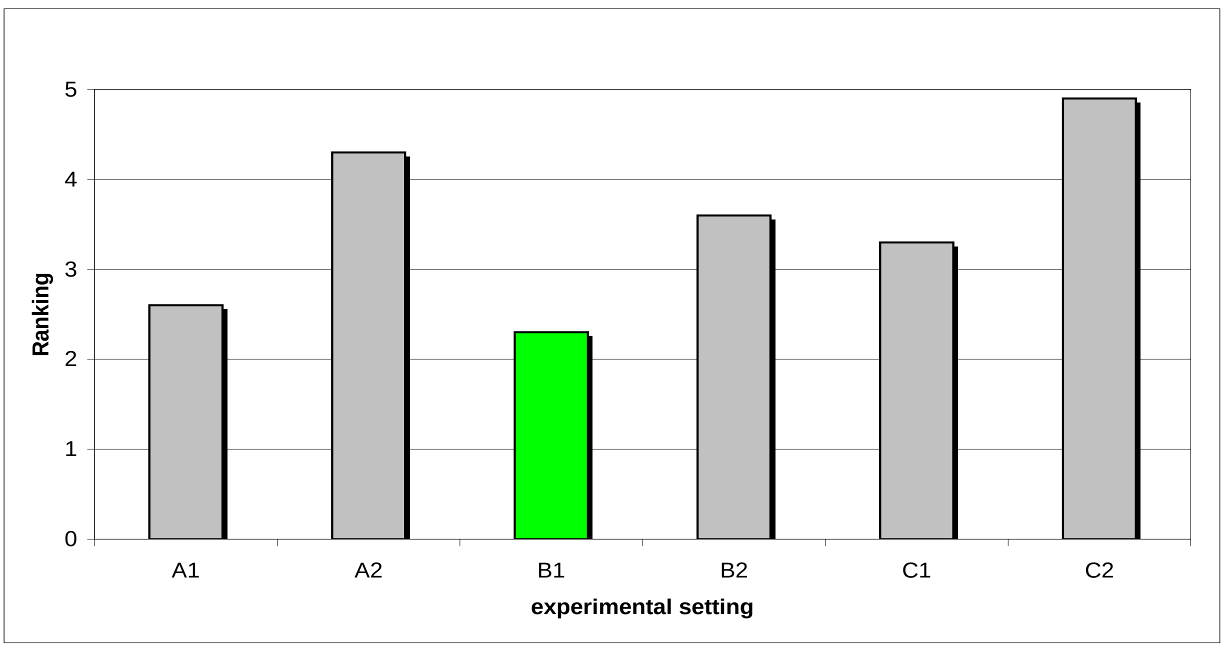

Figure 5: Final ranking of experimental setting regarding all evaluation criteria

The best setting regarding the complete range of assessment criteria turned out to be B1, namely having the teat ends at shoulder height and using a light milking unit.

5. CONCLUSIONS

The high level of MSD amongst milking parlour workers will not of course be due entirely to the geometry in the milking shed design. Other changes associated with increased mechanisation, such as reduced task variety and task autonomy, longer working hours and psychosocial adjustments as milking becomes more specialised may all be factors. Work organisational elements were however beyond the scope of this study.

The ergonomic set up in a milking parlour depends on the body height of the milker, the dimensions of the cow and the construction of the parlour. The situation changes slightly with every cow. It is therefore very hard to analyse the general risk of musculoskeletal pain or fatigue for someone milking cows. It was shown that a sole body posture analysis is also not sufficient to analyse the impact of the named changing parameters. When work is done above shoulder level the arms have to be raised and the back is upright, when the udder is below shoulder level the behaviour is the other way around. A working height on shoulder level would be placed on a middle rank if only body posture is contemplable.

The whole measured range of variation in body posture among all settings was approximately 10° from A to C for the trunk inclination and 20° for the upper arm elevation. The body posture followed the expected patterns, but the absolute differences were too small to be detected by pure observation. Therefore applying a precise motion analysis system is necessary. The postural changes were achieved by small changes in working height (+/- 15 cm respectively). Looking at the full range of influence factors on the working height, there will be found larger differences in practice. Regarding the body height small persons are more likely to find situations comparable to the experimental setting A, and are in consequence more likely to suffer from upper limb disorders. Tall persons again might have to work with a bent back more often and in consequence more likely suffer from low back pains.

The combination of EMG and self evaluation allows the judgement of comfort for different settings -similar to human models used for cab design, etc.. One of the conclusions is that the teat end should preferably be at shoulder level to guarantee the lowest perceived exertion. This is of course hard to put into practice at this point in time, because even if one had an adjustable floor, the adjustment could not be realised for every cow or for two workers of different body heights working at the same time.

Finally, this is the first study known that evaluates the ergonomic design of milking parlours. The results could help farmers designing new milking parlours to best suit their population of cows and workers.

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