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Ergonomic Fitting of Hock Rail Height in Milking Parlours

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Abstract

Many dairy farmers suffer from musculoskeletal ailments, such as upper extremity–associated disorders. Further, they have problems with their knees. As the number of animals in dairy farms has increased, so has the workload. This may lead to a strenuous amount of work especially during milking. Ergonomics affect every person, yet the aim of improving posture in the work environment is often neglected. The change of husbandry systems from tethered housing to loose housing has shifted the milking procedure from sitting milking to standing milking in parlours. Although this shift has been associated with improved posture, health problems in dairy farmers could not be alleviated. The present study aimed at quantifying the workload during the attachment task, which presented the most strenuous task during milking.

The study was carried out on 15 different farms (three farms of each parlour type: autotandem, herringbone 30°, herringbone 50°, parallel, and rotary) with two subjects per farm during one full shift of milking. The posture of milkers was analysed by the CUELA (Computer-Assisted Recording and Long Time Analysis) system. CUELA recorded positions of joints and body regions according to the neutral zero method. The 25th, 50th, and 75th percentiles described the distribution of angular degrees for each joint. The postures were evaluated according to international standards, which rated the angular degrees of joints as acceptable, conditionally acceptable, or not acceptable. A generalised linear mixed-effects model was used to evaluate the data by accounting for the hierarchical experimental design.

The results showed that the interaction between hock rail coefficient (hock rail height divided by milker height in cm) and parlour type had a significant effect on ergonomics. Hence, the ideal hock rail height varied between the different parlour types. Whilst the milkers' ergonomics in the parallel and herringbone 30° parlours benefited from a lower hock rail height, the ideal hock rail heights in autotandem or rotary parlours were higher. No hock rail height at which more than 69% of all joints were in an ergonomically acceptable range could be found in the 25th, 50th, and 75th percentiles. In this work, we developed a hock rail height formula. This formula enabled us to calculate hock rail heights specific to the parlour type and milker's height and to offer recommendations on the ergonomic fitting of hock rail heights in a variety of milking parlour types.

Keywords: guideline, milking health formula, posture, workload, CUELA

1. Introduction

Dairy farming is a high-workload task due to its physical and mental demands. Douphrate *et al.* (2009) reported that 80% of dairy farmers suffered from musculoskeletal ailments, such as arm- and wrist-associated disorders. Although dairy farmers' tasks vary, it has been particularly interesting to evaluate ergonomics during milking. Milking is unique to dairy farming and thus differentiates it from other farm work. Attaching the milking cluster presented the most strenuous duty during milking, as the milker had to lift the milking cluster with one hand and attach each teat cup to the teats with the other hand (Pinzke *et al.,* 2001). The milking cluster could weigh up to 4 kg and needed to be lifted until all four teat cups were attached to the teats. To work with a straight back, the milker had to lift his or her arms, elbows, and wrists. However, the shoulders, elbows, and wrists were in a more acceptable position when their flexion was decreased (IFA-Report, 2013). In a recent study, we developed a milking health formula, which could be used to calculate the ideal depth of pit (in prep., Gansow *et al.*, 2014). The study recommended lower working heights than those currently applied by the machine-milking industry. Furthermore, hock rails appeared to be relevant in regard to ergonomics as the milker was often forced to bend around the lowest hock rail whilst reaching out to attach the teat cups to the teats. The cow's position differed among the milking parlour types (herringbone 30°, **HB 30°;** herringbone 50°, **HB 50°;** autotandem, **ATD;** parallel, **PAR;** and rotary, **ROT**) and affected the angle at which the milker had to reach out to the udder. Thus, ergonomics may have differed in the different milking parlour types.

The current study aimed not only at evaluating the effect of hock rail height on ergonomics during milking but furthermore at offering recommendations on the fitting of hock rails in milking parlours and evaluating body regions of specific concern.

2. Materials and Methods

Data Collection

The study was performed on 15 commercial farms with five different milking parlour types: HB 30°, HB 50°, ATD, PAR, and ROT (three farms per type). Each farm was sampled by monitoring two different subjects (milkers) for the duration of one full shift of milking. Ultimately, each cow on every farm was milked by two milkers. All 30 subjects (4 female, 26 male) were experienced professional milkers and accustomed to milking in the investigated environment. The CUELA system was attached to the subjects and recorded angular degrees of joints, **ADJ** (Ellegast, 1998). An overview of the subjects' heights and the hock rail configurations is given in table 1. The hock rail height was measured from the base of the milking pit to the hock rail that was nearest to the cow's udder (see figure 1).

Table 1: Overview of subjects and parlour configurations in cm.

Parlour type	Hock rail height (mean)	S. d.	Milker's height (mean)	S. d.	**Min**.	**Max**.
Autotandem	164	± 9	173	± 8	160	181
Herringbone 30°	154	± 10	177	± 5	170	183
Herringbone 50°	166	± 5	176	± 5	170	182
Parallel	169	± 5	176	± 5	167	182
Rotary	168	± 10	176	± 5	171	183

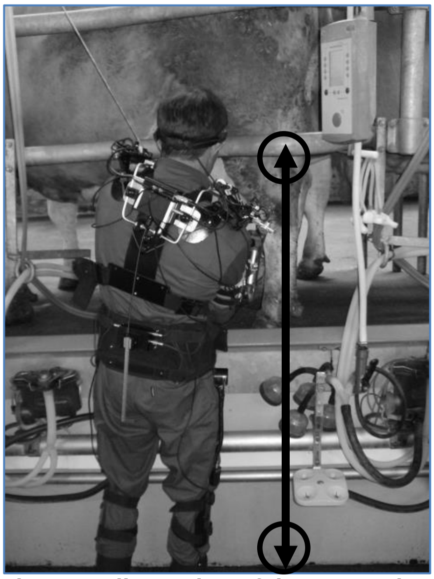

Figure 1: Illustration of the measuring points for the hock rail height.

Data Processing

The WIDAAN software has been specifically developed for the CUELA system and was used to assign the milking procedure for each cow to the individual milking interval (udder stimulation, pre-milking, swinging in the milking cluster, attaching the milking cluster, and dipping or spraying). Only the attachment task was evaluated in the data analysis. The WIDAAN software subsequently produced a range of angular data for each interval. The angular degrees in the 25th, 50th, and 75th percentiles were evaluated according to the neutral zero method. A standard rating was available for 27 joints; each movement could result in various joint positions that were expressed as ADJ and were rated as acceptable, conditionally acceptable, or not acceptable in regard to ergonomics (DIN EN 1005-4, 2002; Drury, 1987; Hoehne-Hückstädt et al., 2007; IFA-Report, 2013; ISO 11226, 2000; McAtamney and Corlett, 1993).

Statistical Analysis

A generalised linear mixed-effects model ('lme' method; Pinheiro and Bates, 2000) was used to evaluate the target variables. Statistical differences were evaluated separately for the 25th, 50th, and 75th percentiles of each ADJ. The statistical analysis was performed in R 1.9.1 (R Development Core Team, 2006), where parlour type (factor with five levels: ATD, HB 30°, HB 50°, PAR, and ROT), hock rail coefficient (continuous), and all possible two-way interactions between parlour type and hock rail coefficient were fixed effects. Cows nested in farms were included as a random effect. The residuals and random effects were checked graphically to assure that they met the model assumptions.

Model Development

The statistical output from the recordings and analyses of the rated ADJ and body regions was used in a mathematical model to calculate the ADJ at specific height coefficients between 0.8 and 1.1 (in 0.02 intervals):

$$\textit{Hock rail coefficient} = \textit{hock rail height (cm)} \div \textit{milker's height (cm)}$$

The statistical data were used to assess the most acceptable posture by summarising the numbers of ADJ that were rated as acceptable (IFA-Report, 2013) at a specific hock rail coefficient. The numbers of acceptable ADJ across all ADJ in the 25th, 50th, and 75th percentiles were counted and summarised for each milking parlour type and hock rail coefficient. If 100% of all modelled ADJ were acceptable, this would result in a total of 25 acceptable occurrences in each of the three percentiles and thus a maximal score of 75.

3. Results and Discussion

In regard to the hock rail height, the data revealed that the interaction of the hock rail coefficient and the parlour type affected the posture during milking. The interaction was significant ($P < 0.05$) in 31 out of 31 ADJ across the 25th, 50th, and 75th percentiles. This implicated that the hock rail height needed to be fitted according to the hock rail coefficient not only to the individual parlour type but also to the milker's body height. To provide applicable recommendations, we identified the most acceptable hock rail height for the various milking parlour types and milkers' heights (hock rail coefficient). The model data were used to create a range of data on ergonomics across the parlour types to then conclude the most acceptable hock rail heights. Table 2 presents the modelled ADJ which were in an acceptable posture depending on the hock rail coefficient and the milking parlour type.

Table 2: Number of acceptable ADJ across different hock rail coefficients in the 25th, 50th, and 75th percentiles for five milking parlour types. If all ADJ were in an acceptable position, this would result in a score of 75. The recommended hock rail coefficients for each parlour type were indicated by the boxes.

Parlour type	Hock rail coefficient								
	0.86	0.88	0.90	0.92	0.94	0.96	0.98	1.00	1.02
Autotandem	41	41	46	46	48	50	49	51	50
Herringbone 30°	44	47	45	41	34	30	29	27	23
Herringbone 50°	32	41	47	52	51	45	39	33	28
Parallel	41	43	45	43	43	44	43	44	41
Rotary	13	15	20	25	41	44	38	35	31

It was apparent that the ROT parlour had the lowest number of acceptable ADJ (44 acceptable out of 75 total ADJ) at its most acceptable hock rail coefficient. The PAR parlour had one more acceptable ADJ (45 out of 75) at its most acceptable hock rail coefficient. The HB 50° parlour had the largest number of acceptable ADJ (52 out of 75). Further, at hock rail height coefficients between 0.96 and 1.02, the ATD parlour was more tolerant in the ideal hock rail height than the ROT parlour. This could be concluded as the number of acceptable positions across these coefficients for the ATD parlour varied by only 1-2, whereas that for the ROT parlour varied by 6-13 (see table 2). No hock rail height at which all ADJ were in an acceptable range could be found for any parlour type, yet it was possible to develop a formula that facilitated the calculation of the most acceptable parlour-specific hock rail height:

Milker's height (cm) × parlour-specific hock rail coefficient = ideal hock rail height (cm)

The recommended parlour-specific hock rail coefficients were indicated in table 2. These recommendations offer an easily applicable way to calculate the ideal hock rail configuration. For example, the ideal hock rail configuration for a 170 cm tall milker would have the lowest hock rail at 170 cm in an ATD parlour and at 150 cm in an HB 30° parlour. Although it was logical that hock rail height should be adjusted to fit the milker's height, it had not been clear how this could be applied to the praxis. Results showed that ergonomics in milking parlours were dependent on the parlour type, likely because the cow's position and thus the udder accessibility differed in each parlour type. For instance, the HB and PAR parlours allowed the milker to step close to the cow's udder, whereas the distance between the milker and the udder was larger in the ATD and ROT parlours. Although the ROT parlours evaluated in the current study were herringbone shaped with the milker standing inside and the cows standing at an angled position, the circular shape of the cows' floor forced the milker to stretch out to reach the udder, just as it was required in the ATD parlour.

As shown in table 2, the ideal coefficients for ROT and ATD parlours were 0.96 and 1.00, respectively, indicating that the lowest hock rail should be fitted no lower than the milker's height. This fit allowed the milker to work underneath the hock rail without being in an awkward posture. However, the situation in the HB and PAR parlours was different. These parlours allowed the milker to step close to the cow's udder and hence did not require the milker to reach far. The hock rail coefficients advised for these parlours were lower than those recommended for the ROT and ATD parlours (HB 30°: 0.88; HB 50°: 0.92; and PAR: 0.90). The range of coefficients from 0.88 to 0.92 implied that about 10% of the milker's upper body should be above the lowest hock rail. Hence, according to the results, the milker benefited when his or her head was above the lowest hock rail. However, the hock rail offers protection to the milker as it hinders the cow from kicking or stepping outside of its milking place. As the cow has little space in the HB 30°, HB 50°, and PAR parlours, it seems practical to advise that the hock rails be installed at a low level and thus confine the cow's legs. In an ATD parlour, the cow has more space available to step or kick within the milking place, so it is less likely to kick the milker. Here, installing the hock rail at a level above the milker's head would not increase the risk of injury.

The body regions predominantly affected by poor ergonomics were the elbow, head and neck, shoulder, hand, and knee regions (figure 2). Thus, the ergonomic weighting of specific joints should be reconsidered for the milking environment. Although it was apparent that a straight back was vital, the back was rarely subjected to postures rated as not acceptable or conditionally acceptable during milking. This result can be explained by the ergonomic classification of back postures shown in figure 3, which indicates that only extension of the back and flexion to an angle greater than 20° are classified as conditionally or not acceptable (IFA-Report, 2013). Contrary, the consequences of the movements of the body regions presented in figure 2 should be evaluated in further detail.

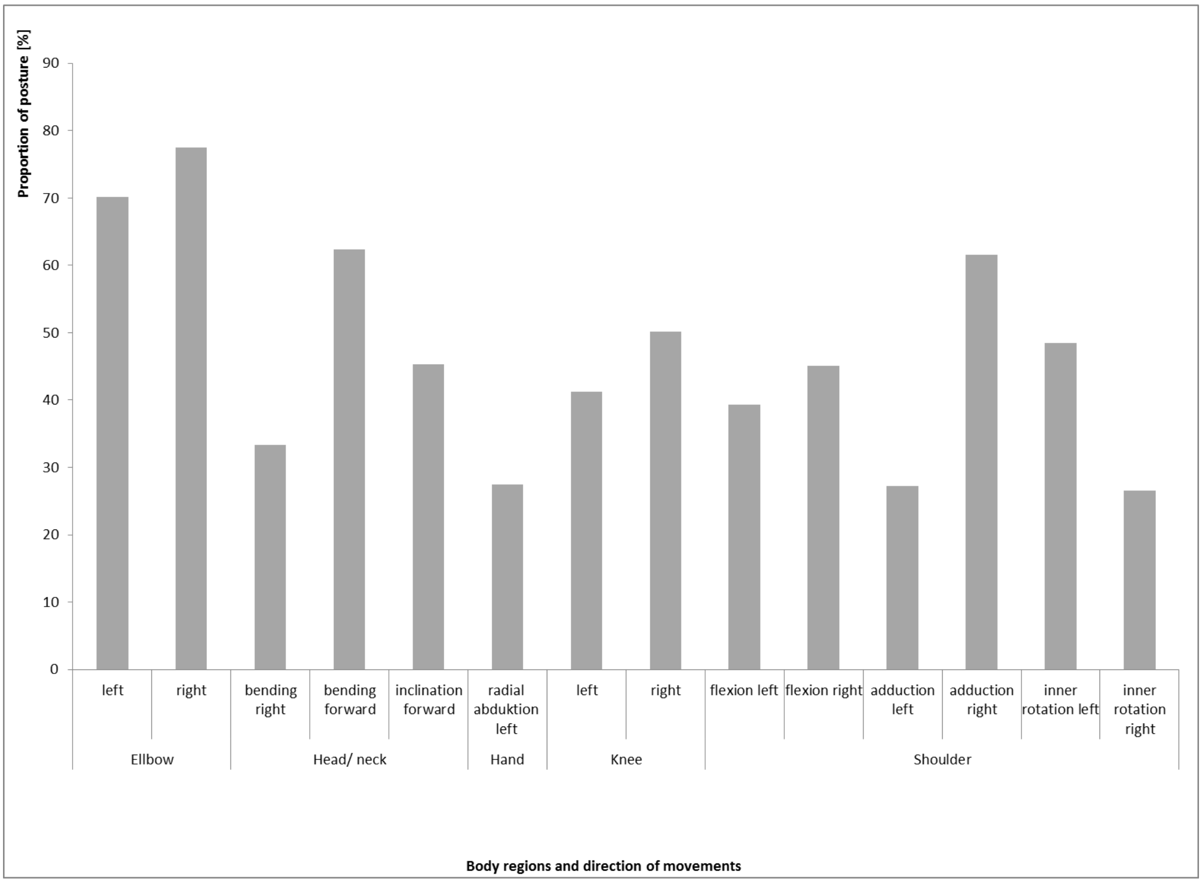

Figure 2: Median level (in %) of postures rated as not acceptable during the attachment task (from raw data).

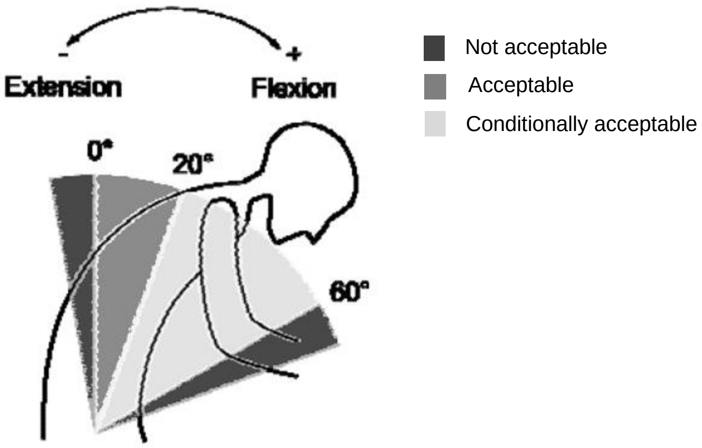

Figure 3: Ergonomics of trunk inclination (IFA-Report, 2013).

The problems reported previously by milkers were usually not back related but included mainly the neck, shoulder, and upper extremities (Jakob *et al.,* 2012). This was confirmed by the findings of the current research (see figure 1 for further information). Gansow *et al.* (2014; in prep.) further found that decreasing the working height reduced the height to which the milker had to lift the milking cluster and thus decreased the level of bending in the shoulders and elbows.

The results of the current study indicated that an adjustment of the hock rail height improved the ergonomics during milking. The adjustment reduced the necessity of bending the head and neck and made it easier to work around the hock rail. This effect is demonstrated in figure 4, which shows that the ergonomics of the head and neck regions were affected by the hock rail coefficients and the parlour type. It appeared that ergonomics of the head and neck regions were beneficial in the HB 50° parlour and poorest in the ROT parlour. These findings were developed from model data; therefore, future research is needed to validate them in a practical setting.

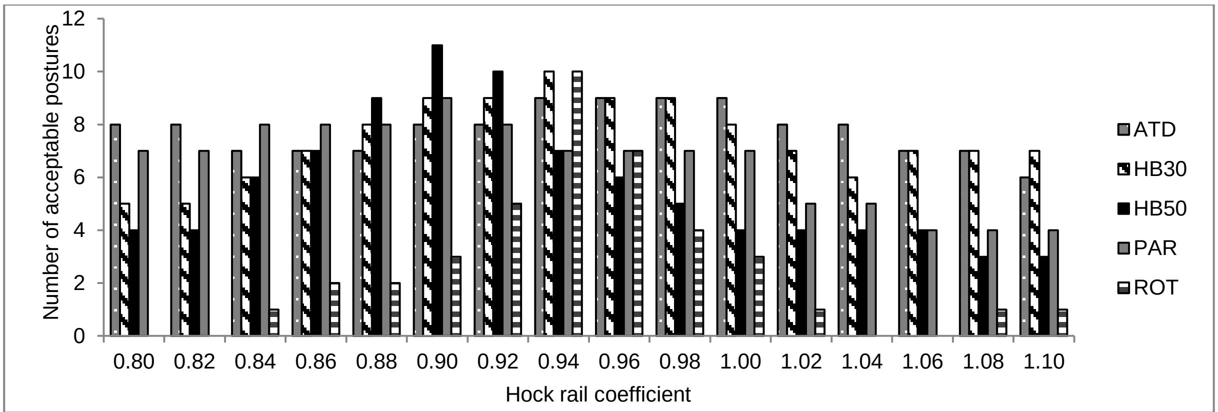

Figure 4: Number of acceptable postures of the neck inclination towards the right and forward as well as the head inclination forward and to the side during the attachment task at different hock rail coefficients in the 25th, 50th, and 75th percentiles (maximum score: 12).

4. Conclusions

Ergonomics during milking were influenced by the interaction of the milking parlour type and a hock rail coefficient. Currently, hock rail configurations in milking parlours are standardised and do not consider the milker's height in the design of milking parlours. In this study, we developed a parlour-specific formula that could be used to easily adjust hock rails in existing and new parlours.

5. Acknowledgements

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