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Comparison of claw horn disruption lesions in four dairy herds using two different trimming techniques: A case study

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ABSTRACT

Claw disorders are a major problem for health, welfare, and economy in dairy production. This retrospective observational study investigated the association between cow-level prevalence of claw horn disruptive lesions and two different trimming methods - the traditional Danish Method (DAM) and the White Line Atlas Method (WLAM). Trimming records from four herds in Denmark over a 4-year period were analysed. Within each herd, claw trimming was performed with the DAM for the first 2 years, and the WLAM for the next 2 years. The data comprised 3316 claw trimmings of 1027 cows with the WLAM and 3898 claw trimmings of 1080 cows with the DAM. The association between claw trimming method and claw lesions was determined using binominal logistic analysis. There were significant differences between trimming methods for sole haemorrhage (odds ratio = 0.44), sole ulcer (odds ratio = 0.42), and white line separation (odds ratio = 0.64), with a lower prevalence during the period of trimming with the WLAM. No significant difference between trimming methods could be found in the occurrence of white line abscess or double sole. The lower prevalence of claw horn disruption lesions found in this study when cows were trimmed with WLAM justifies and necessitates further experimental studies of claw trimming methods to validate these findings.

Introduction

Claw lesions in cattle constitute a world-wide economic, health and welfare issue for dairy cattle. Dutch studies found approximately 70% of the dairy cattle have one or more claw lesions at trimming (van der Waaij et al., 2005; van der Linde et al., 2010), while Bruijnis et al. (2010) estimated an annual loss of US$75[1] per cow with claw lesions.

The purpose of claw trimming is to retain or re-establish normal claw function by restoring correct weight-bearing and trimming excessive horn (van Amstel et al., 2002). Assessment of weight distribution before and after trimming have shown that trimming alters and can produce a more even distribution of the weight load on the claw, the foot and on the legs (van der Tol et al., 2004; Carvalho et al., 2006; Ouweltjes et al., 2009). Only a few studies have investigated the effects of claw trimming on claw lesions. Bi-annual trimming can reduce the prevalence of claw horn disruption lesions (CHDL) compared to annual treatment (Manske et al., 2002), while milk yield increases after claw trimming, an indicator of improved claw health (Sogstad et al., 2007). Somers et al. (2003) demonstrated that trimming can be both preventive and curative, while Shearer and van Amstel (2017a) showed that trimming can cure white line disease. Several factors of claw trimming affect CHDL prevalence, including the frequency of claw trimming and the timing of trimming within the lactational cycle (Manske et al., 2002; Tarlton et al., 2002; Bergsten et al., 2019; Thomsen et al., 2019). Differences between claw trimming methods can affect CHDL prevalence[2] (Sadiq et al., 2021). While claw trimming can prevent claw lesions, conversely, incorrect trimming can induce claw lesions (Bergsten, 2001; van Amstel et al., 2002; Shearer and van Amstel, 2017b).

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[1] US$75 in 2010 = approximately US$102 in August 2022. UK£ 1 = approx. US$1.17, €1.17 at 18 August 2022.
[2] See: Stoddard, G., 2018. Evaluating the relationship between hoof trimming and dairy cattle well-being. PhD Thesis. University of Minnesota Digital Conservancy, https://hdl.handle.net/11299/196526 (Accessed 18 August, 2022)

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The Danish Method (DAM)[3] of claw trimming, first described by Fitzbøger and Smedegaard (1955), focuses on correcting the toe angle by trimming the sole in the anterior part of the claw and distributing the weight evenly over the sole. The toe angle of the claw is determined by the amount of horn in the toe and when the toe is overgrown the toe angle is reduced. A reduced toe angle that results from overgrowth forms a lever effect, resulting in extra weight on the posterior part of the sole. Together with the combination of an unyielding surface, such as concrete flooring, a reduced toe angle will put strain on the deep flexor tendon of the third phalanx. This may increase the risk of contusion of the corium, resulting in the development of sole haemorrhage (SH) and sole ulcer (SU). Danish claw trimmers have advocated continuous shorter claw trimming intervals. Even with trimming intervals of 3–4 months, claws can be overgrown on the anterior sole horn causing decreased toe angles, with little improvement in claw health (Capion et al., 2021). Trimming with The White Line Atlas Method (WLAM) was described in 2017 [4] with a focus on improving the stride by trimming the claw in relation to the foot's individual heel fulcrum and providing a breakover point in the toe. Quantification of differences in claw health between the two methods has not been reported.

The aim of the study was to evaluate the prevalence of CHDL in dairy cows trimmed using these two different trimming methods. The hypothesis was that cow-level prevalence of CHDL is the same with two different trimming techniques. The objective was to compare the claw health records of CHDL found at trimming in four dairy herds over a 4-year period, where the cows were trimmed using the two trimming methods for 2 years each.

Materials and methods

Trimming methods

The two trimming methods investigated were the DAM and the WLAM. The DAM seeks to ensure a toe angle of 45–52° (Fig. 1). The DAM method follows these principles: 1. Cut the sole of the largest claw (lateral hind claw, medial front claw) to achieve a toe angle of 45–52° leaving 8–10 mm sole horn; 2. If possible, the heels should be cut to the same height; 3. Model the sole ulcer site at a depth of 5 mm[2]. The DAM differs from a similar method (known as the Dutch Five Step Method) by not cutting the toe to a specific length. The Danish method also often leaves more height in the heel of the largest claw (lateral hind claw, medial front claw) compared to the small claw to achieve the toe angle.

The WLAM focuses on supporting the cow's daily routine of standing, moving and lying down. The intension is to provide a claw trimming where all biomechanical forces are in balance during everyday activities. The method defines the claws as 'the stabilizer claw' (lateral front claw, medial hind claw) and 'the stress claw' (lateral hind claw and medial front claw), where the stabilizer claws act as reference points to assess trimming of the stress claws. Five anatomical/functional characteristics, called biomarkers, provided by almost every cow, can be used to guide the claw trimmers towards a balanced claw. Three of the five biomarkers, as shown in Fig. 2, are: the heel fulcrum, where the heel horn and sole horn meets and forms a centre for the rotation of the claw during the stride; the pressure ridge, the strongest part of the abaxial wall just in front of the heel fulcrum; and the breakover point, that simulates the cows natural wear in the toe and allows a smoother stride and a self- regulating ability of cattle to maintain normal claw structure. The final two biomarkers are the white line of the claw and normal sole thickness. Normal sole thickness is defined as the hydrated, elastic sole horn, underneath the dry flaky horn, that allows the wall to be weight bearing[4]. Trimming is performed in four steps (Fig. 3). The heel fulcrum of the stabilizer claw defines the height of both claws and creates balance between the claws and trimming the axial wall close to 90-degree angle to the floor creates balance within the claw. The trimmer should keep stable axial walls intact between the claws. The most noticeable difference between the two methods is that the DAM trims to a certain pre-defined toe angle whereas the WLAM trims according to the toe axis and the heel fulcrum to enhance the breakover point using measurements defined by the conformation of the cow and visualised by the biomarkers.

Dataset

A claw trimmer (one main trimmer and one assistant trimmer) had serviced herds in the region of Zealand during the past 20 years. Prior to the fall 2018, this trimmer used the DAM, but changed subsequently to the WLAM. Of the approximately 50 herds serviced by this trimmer the authors identified four herds (A-D) in which there had been no substantial changes during 2016–2020 in key aspects of farm management, including housing, flooring or trimming frequency. In this region, trimming records were captured electronically at the time as trimming using the Nordic claw health atlas[5] and Klovregistrering software.[6] Records of routine trimmings and information on cow characteristics between August 1, 2016 and September 15, 2020 in these four herds were extracted from the Danish Dairy Management System. In these herds, cows were trimmed with DAM from August 1, 2016 to September 30, September 2018 and with WLAM from January 1, 2019 to September 15, 2020. The 3-month intervening period was excluded as a transition period between the two methods. One of the herds (D) was sold in May 2020, and no data from this herd from May 2020 to September 2020 was available. Cows were trimmed at 4-monthly intervals in all herds. Table 1 presents information on herd characteristics (size, breed, milking system and flooring). The data structure can be described as repeated cross-sectional samples within each herd supporting a cow-level analysis of lesion prevalence.

The dataset consisted of 3898 claw trimmings of 1080 cows with the DAM and 3316 claw trimmings of 1027 cows with the WLAM. The whole dataset included 1623 cows trimmed with either DAM or WLAM and 484 cows trimmed with both methods. Trimming dates where less than 20 cows were trimmed were omitted from the dataset, because these were considered an emergency trimming based on acute symptoms and the trimming would then be curative rather than preventive.

In the analysis the following CHDL were included: SH, a red or yellow discoloration of the sole horn; SU, lesion in the sole with exposed corium; White Line Separation (WLS), separation in the white line present with no exposure of corium; White Line Abscess (WLA), separation in the white line with exposed corium with or without purulent exudate; and Double Sole (DS), one or more separate layers of sole horn [4]. All lesions were recorded cow-side on leg-level and the results are presented as the proportion of cows with no lesions, or one, two, three and four different CHDL. For analysis, the lesions were aggregated to cow-level as either absence or presence (e.g. a cow was treated as having SH if SH was recorded on at least one leg). Lesions found on one or several legs and the severity of lesions depend on lesion development, sole thickness, claw wear and timing of trimming. Discoloured sole horn can be worn

[3] See: Kompendium om klovpleje for landmænd.https://www.dropbox.com/sh/ul7e2dyjsy24f2s/AABIs7VrxI0fBuqhwZU6MZSya?dl=0&preview=Kompendium+om+klovpleje+for+landm%C3%A6nd+PDF+ (1).pdf (Accessed 18 August, 2022).

[4] See: A Treatise on Cattle Foot Trimming. The White Line Atlas Method. https://vicshooftrimmingcourse.ca/class-information/#course-schedule (Accessed 18 August, 2022).

[5] See: Nordisk klovatlas.https://sp.landbrugsinfo.dk/Kvaeg/Sundhed-og-dyrevelfaerd/produktionssygdomme/Klove-og-lemmer/Sider/Nordisk-Klovatlas-DK.pdf?download=true" (Accessed 12 August, 2022).

[6] See: Klovregistrering.https://www.landbrugsinfo.dk/Kvaeg/Sundhed-og-dyrevelfaerd/produktionssygdomme/Klove-og-lemmer/Sider/Klovregistrering-sprogram.aspx. (Accessed 12 August, 2022).

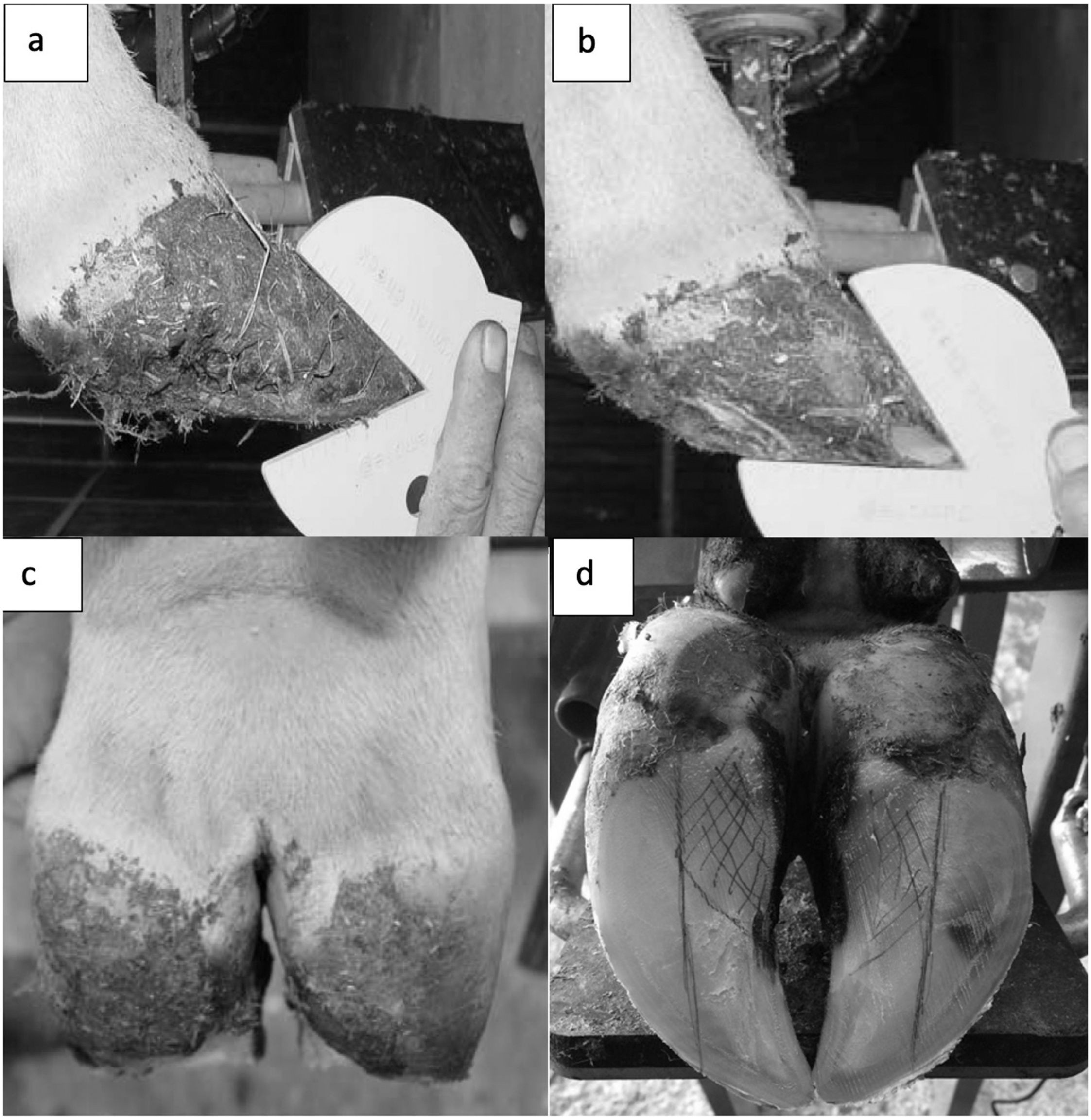

Fig. 1. The Danish Method of hoof trimming: a) toe angle is evaluated on the large claw (lateral hind, medial front); b) starting from the large claw the sole is cut in the toe to fit the angle 45–52° leaving 8–10 mm of sole thickness; c) heels are cut at the same height if possible; d) the model is cut at a depth of 5 mm in the marked area.

off between trimmings or removed during trimming. Days in milk (DIM) at claw trimming was calculated as the days between calving and the trimming. The cows were grouped according to parity as 1, 2 or $\geq$ 3. The proportion of cows with the same lesion recorded on one or more legs among the total number of cows recorded is presented for each trimming method.

Statistical model

Analyses were made as a mixed effects binominal logistic model with a random intercept for each cow to account for individual cows having several trimmings. Parity group and DIM at trimming were included as covariates and herd was included to account for the multi-centre origin of the data. Initial analyses included interactions between parity and method as well as herd and method, and demonstrated that the interaction between parity and method were never significant ($P > 0.20$) whereas the interaction between herd and method were significant in two (SH, $P = 0.04$; WLS, $P = 0.05$) of the five analyses. The parameter estimates revealed that this interaction did change the magnitude of the association to method but never the direction of the association. To assure model consistency across the analyses no interaction was included; instead, the effects of herd were evaluated using leave-one-herd-out cross validation.

In the analyses, y_{ij} is the result of either SH, SU, DS, WLA or WLS in cows (j) at trimming (i), which can take the value 0 (lesion absent) or 1 (lesion present). Then y_{ij} is a realisation of the random variable Y_{ij} where $Y_{ij} \sim \text{Binominal}(1,\pi_{ij})$ and $\pi_{ij} = \Pr(y_{ij}=1)$. The analysed model is described as:

$$Logit(\pi_{ij}) = \beta_{0j} + \beta_1 Method + \beta_2 Herd + \beta_3 Parity + \beta_4 DIM + \beta_5 DIM^2$$

where i = the individual trimming and j = the cow.

β_{0j} is the random intercept of the model which consists of $\beta_0 + u_{0j}$.

β_0 is the overall intercept of the model at Method = DAM, Herd = A, Parity = 1.

u_{0j} is the random contribution of each cow j and assumed $u_{0j} \sim N(0, \sigma^2_{u0})$.

β_1 = Coefficient for difference in trimming method, using DAM as a reference.

β_2 = Coefficients (3) for the differences between Herd B, C and D and

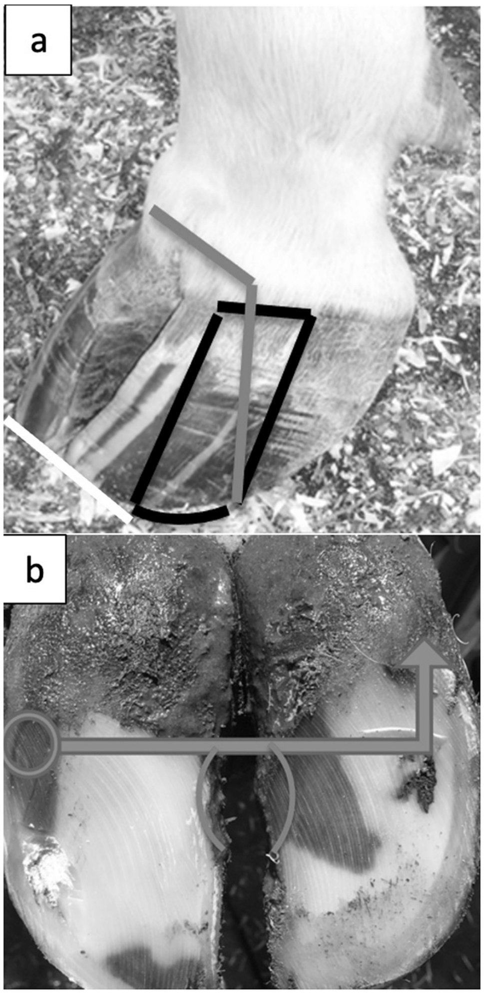

Fig. 2. Biomarkers for the White Line Atlas Method: a) grey line indicates the heel fulcrum and black box indicates the pressure ridge and the white line indicates the break over point; b) grey line indicates the heel fulcrum from the sole surface, just above the axial groove indicated by the arch.

Herd A.

β_3 = Coefficients (2) for the differences between Parity 2 and $\geq$ 3 and Parity 1.

β_4= Coefficient for the linear effect of DIM.

β_5 = Coefficient for quadratic effect of DIM.

The data was edited and analysed using R version 4.0.35.[7] The logistic analyses were done with the glmer-function using Maximum Likelihood estimation from the lme4-package (Bates et al., 2015). A significance level of $P = 0.05$ was used.

Cross-validations were done at both herd and cow level. The potential effect of herd on the parameter estimates was investigated by leave-one-herd-out cross validation. The statistical models were run four times, where one herd was excluded each time and the parameter estimates compared. At the individual level, 20% of the cows were randomly selected by the sample-function provided by base R and removed from the data set, separately for each lesion. This resulted in five subsets of data and the statistical models were then re-run on the new randomly reduced datasets and the parameter estimates were compared.

STROBE guidelines were followed and a STROBE statement was prepared (Supplementary file).

Results

As shown in Table 1, a noticeable difference between the herds is the size of herd D, which was less than half of the others. Another difference was the breed in herds A, B and C which was Red Danish dairy whereas herd D had Danish Holsteins.

Table 2 shows the cow level prevalence of CHDL of cows trimmed with the two methods stratified across the four different herds. The highest prevalence was found for SH in herd D at 58.7% and WLS in herd B at 29.5%, when recorded during the DAM period. The highest prevalence was 41.3% for SH in Herd D and 22.4% for WLS in herd B during the WLAM period. DS and WLA had a cow prevalence rate of approximately 10% and less than 5% respectively depending on herd and trimming method. The largest descriptive difference was seen for SU in herds B, C and D where the prevalence of SU was reduced by more than half when trimmings with WLAM were compared to DAM. The proportion of cows without lesions increased and the proportion of cows with two or more lesions per recording decreased during the WLAM period. The percentage of heifers trimmed in both periods varied in herds A, B and D between the periods. The percentage of other age groups trimmed were similar within herds, except for herd A where the group of third lactation and older cows was reduced in the WLAM period. The proportion of lactation stages were similar in the two trimming periods.

Lesions were recorded on leg level and the distribution of recordings on one, two, three or all legs were similar in the two periods (Table 3). SH were recorded primarily on one or two legs, SU and DS were primarily on one leg and WLA was only recorded on one leg. Only one cow was recorded with all five lesions at the same recording.

Table 4 presents the parameter estimates, standard errors and *P*-values for the multivariable models by CHDL outcome, either SH, SU, WLS, WLA or DS. Table 4 shows that trimming method had a highly significant effect ($P < 0.001$) on the odds of SH, SU, WLS and a significant effect on WLA ($P = 0.04$). Trimming method was not significant for DS lesions ($P = 0.28$). Herd was significant for SH ($P = 0.04$), SU ($P < 0.0001$) and DS ($P < 0.0001$). Parity was significant for all lesions ($P < 0.001$), whereas DIM was significant for SH ($P = 0.002$), SU ($P < 0.002$) and WLS ($P = 0.04$).

Table 5 presents the adjusted odds ratios and the 95%-confidence interval for the odds ratios for the difference between the trimming methods for the models SH, SU, WLS, WLA and DS based on the statistical models. The odds ratios show that the odds of the four significant types of CHDL are between 0.64 times and 0.42 times lower for the cows that had been trimmed using the WLAM, with the largest effect being on sole ulcer and sole haemorrhage. In the analysis of DS, the trimming method was not significant ($P = 0.27$).

To determine whether the models were highly influenced by a limited number of cows, the models were re-analysed five times, randomly omitting 20% of the cows, creating unique subsets of the original data. The cross-validation results showed that trimming method were significant for all five subset-analyses of SH ($P < 0.001$), SU ($P < 0.001$) and WLS ($P < 0.001$). The interval of odds ratios in the subset analyses were 0.43–0.46 for SH, 0.36–0.48 for SU and 0.62–0.68 for WLS. In the subset analyses of WLA, trimming method were only significant in one of the five subsets ($P = 0.05$, remaining four subsets, $P > 0.15$), while for DS trimming method was not significant for any of the subsets ($0.30 < P < 0.53$). Leave-one-herd-out-cross validations were undertaken by re-running the analyses after omitting one of the four herds from the data. The results showed that trimming method was significant in all analyses of SH ($P < 0.001$), SU ($P < 0.001$) and WLS ($P < 0.001$). The estimate of the odd ratios for trimming effect were in the range 0.41–0.49 for SH, between 0.36 and 0.46 for SU and between 0.58 and 0.68 for WLS. Trimming method was not significant in the WLA

[7] See: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/ (Accessed Aug 18, 2022)

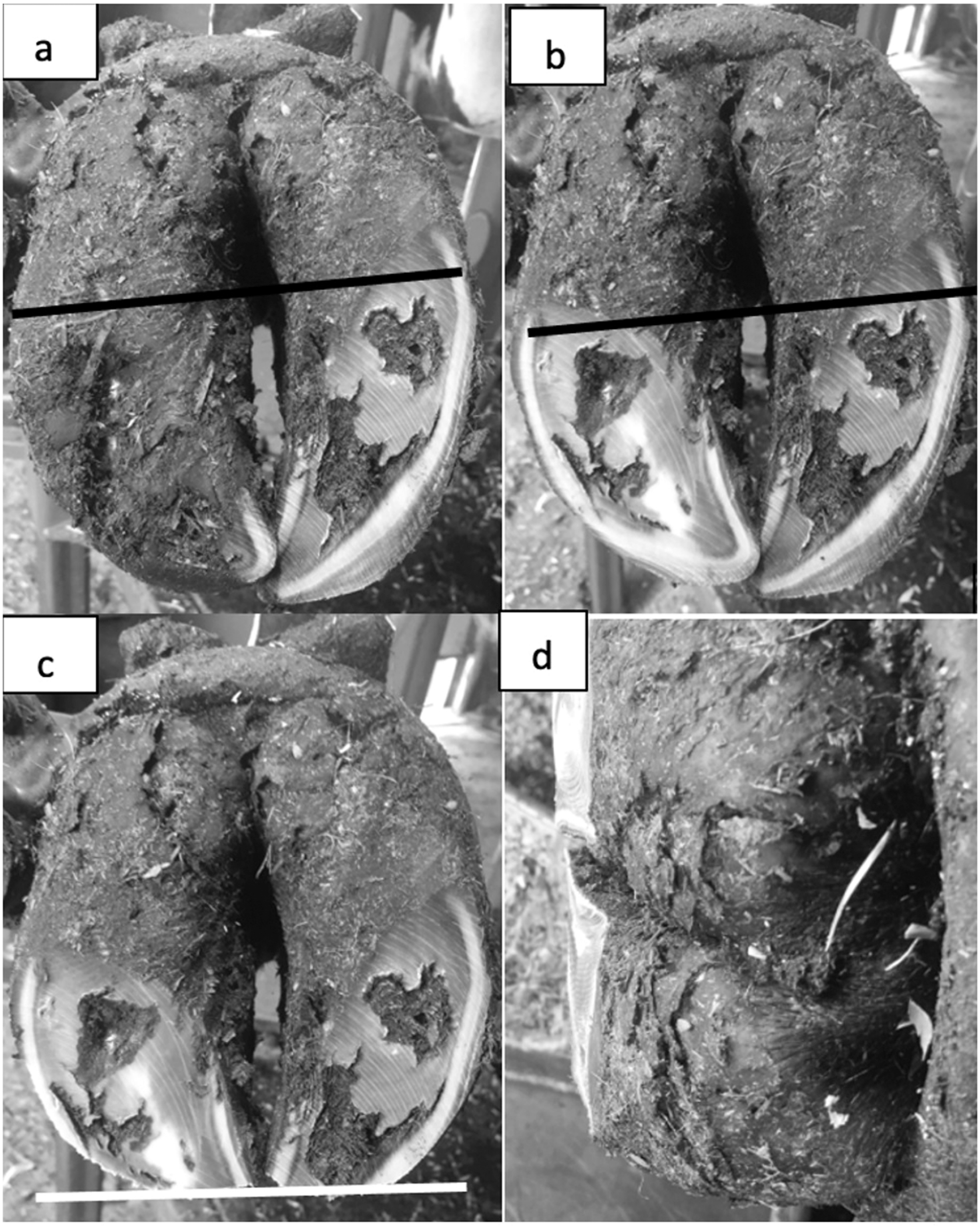

Fig. 3. White Line Atlas Method trimming in four steps: a) height of the heel fulcrum from the stress claw are cut to the height of the stabilizer claw; b) stabilizer claw is cut flat; c) the breakover point is cut in the toe; d) the claws are cut to the same height and checked. Black lines indicate the heel fulcrum, white line indicates the breakover point.

analysis if Herd A ($P = 0.82$), C ($P = 0.41$) or D ($P = 0.42$) was removed from the data and trimming method were never significant in the analysis of DS regardless of the subgroup of herds that were included in the analysis ($P > 0.19$ for all four analyses).

Discussion

This observational case study analysed the association between CHDL and trimming method in four Danish dairy herds. Claw lesions were recorded on leg level and the proportion of legs affected was similar in the two periods. The results showed that the odds of CHDL (SH, SU, WLS) were significantly lower with the WLAM trimming method. There was a lower prevalence of WLA in all herds and DS in two out of four herds in the period with WLAM, however the findings were not significant.

Prevalence of CHDL increases with lactation number, and thus older cows have the highest prevalence (Capion et al., 2021). Our study showed the proportion of age groups were similar in the two trimming periods, except for herd A where the proportion of third lactation and older cows was reduced from 31% in the DAM period to 23% in the

Table 1
Herd information for four free-stall herds investigated, showing herd size, breed, milking system and flooring type.

	Herd A	Herd B	Herd C	Herd D
Cows with 365 feeding days[a]	205.2	202.7	196.8	90.8
Breed	Red Danish dairy	Red Danish dairy	Red Danish dairy	Danish Holstein
Milking system	Herringbone	Herringbone	Automatic	Herringbone
Concrete floor	Solid	Slatted	Slatted	Slatted
Barn type	Loose housed Cubicles	Loose housed Cubicles	Loose housed Cubicles	Loose housed Cubicles

[a] Average number of cows present per herd per year, accounting for heifer calvings and cows leaving the herd

WLAM period, and this could explain the lower prevalence in this herd. The risk of CHDL also increases with CHDL in previous lactations (Oikonomou et al., 2013). While this would mean that CHDL during the DAM period would be likely to increase the risk of CHDL in the WLAM period, the data did not support this outcome. In addition, there is an increased risk of CHDL in the period after calving (Green et al., 2002; Lim et al., 2015) and as the distribution of lactation stages were similar in the two trimming periods, this would suggest that the prevalence in both periods was equally affected.

Claw health and claw trimming are strongly related. If the WLAM compared to the DAM succeeds with trimming the claw to a more optimal conformation for the lamellar-laminar junctions, it follows that the SH, SU and WLS would be reduced (Ossent and Lischer, 1998; Shearer and van Amstel, 2017b). The lower prevalence of SH, SU and WLS when cows were trimmed using WLAM could be explained by

Table 3
Proportion (%) of sole haemorrhage (SH), sole ulcer (SU), white line separation (WLS), white line abscess (WLA) and double sole (DS) lesions recorded on 1, 2, 3 or all legs on cows trimmed with two claw trimming methods: White Line Atlas Method (WLAM) and Danish Method (DAM).

Method		Legs affected			
		1	2	3	4
WLAM	SH	42.4	41.5	5.2	10.7
	SU	86.5	12.7	0.4	0.4
	WLS	77.1	19.3	3.0	0.5
	WLA	100	0	0	0
	DS	85.8	11.3	2.0	0.8
DAM	SH	42.9	40.6	9.7	6.7
	SU	81.7	16.2	1.6	0.5
	WLS	66.3	26.2	5.9	1.5
	WLA	100	0	0	0
	DS	86.0	10.6	3.0	0.4

Table 2
Distribution of age groups and days in milk within four dairy herds (A-D) trimmed with two claw trimming methods: Danish Method (DAM) and White Line Atlas Method (WLAM). The number of claw trimmings and cow-level prevalence of sole haemorrhage (SH), sole ulcer (SU), white line separation (WLS), white line abscess (WLA), and double sole (DS), and the number of different lesions recorded per cow are shown.

	Herd A		Herd B		Herd C		Herd D	
	DAM	WLAM	DAM	WLAM	DAM	WLAM	DAM	WLAM
Heifers[a]	7.5	4.1	1.6	0.8	1.4	0.8	4.3	1.1
Parity 1 cows[a]	34.8	32.2	36.9	39.4	45.9	43.2	38.5	44.1
Parity 2 cows[a]	22.7	26.1	28.6	29.2	29.1	27.5	26.0	31.6
Parity ≥ 3 cows[a]	35.0	37.6	32.9	30.6	23.6	21.1	31.3	23.3
Days in milk[b]	27.5	30.3	35.2	38.0	26.2	29.4	24.2	23.6
0–100[a]	22.0	23.6	18.0	16.6	26.3	23.1	25.1	25.7
100–200[a]	23.0	23.6	31.1	30.9	23.5	19.1	23.2	26.0
200–300[a]	19.9	18.4	14.0	13.7	22.5	20.2	23.3	23.6
> 300[a]								
Claw trimmings	772	967	1225	990	1211	1013	690	346
Overall prevalence SH (%)	49.7	36.9	51.2	38.8	57.3	37.7	58.7	41.3
Lactation 1 cows	42.3	31.7	49.5	43.5	52.0	37.5	57.8	32.5
Lactation 2 cows	53.1	37.1	50.8	30.2	58.8	38.9	55.8	40.4
Lactation ≥ 3 cows	55.0	41.4	53.4	40.8	65.9	36.6	62.2	60.0
Overall prevalence SU (%)	12.0	7.1	17.4	7.4	13.4	6.8	5.6	0.9
Parity 1	6.2	3.3	11.1	4.6	8.2	2.7	1.8	1.3
Parity 2	9.9	5.8	14.3	5.2	14.2	8.5	4.3	0
Parity ≥ 3	19.4	11.5	27.0	13.1	22.4	12.8	11.6	1.3
Overall prevalence WLS (%)	24.1	20.4	29.5	22.4	24.0	16.3	25.5	12.7
Parity 1	15.1	15.9	17.6	11.2	15.1	10.1	18.4	10.8
Parity 2	21.9	15.4	31.5	24.1	27.6	19.1	22.3	13.8
Parity ≥ 3	34.6	27.8	41.0	35.3	36.9	25.1	36.9	15.0
Overall prevalence WLA (%)	2.5	1.6	4.5	3.5	3.0	1.8	0.9	0
Parity 1	2.1	0.3	3.2	2.3	0.7	0.8	0.7	0
Parity 2	1.0	2.3	4.2	2.7	4.1	2.6	1.1	0
Parity ≥ 3	3.8	2.1	5.4	5.9	5.9	2.6	0.9	0
Overall prevalence DS (%)	10.2	10.4	16.8	12.4	10.1	8.8	9.1	9.5
Parity 1	4.1	6.3	7.6	8.7	5.3	4.8	6.4	5.1
Parity 2	11.5	7.7	16.8	8.2	8.4	10.9	7.0	9.1
Parity ≥ 3	15.6	16.0	27.1	27.0	21.7	14.0	14.2	18.8
Different lesions	38.0	47.4	28.0	43.6	28.9	49.3	28.5	48.9
None[a]								
One[a]	39.4	36.6	38.5	34.4	43.5	37.2	46.9	39.8
Two[a]	17.4	12.5	24.0	16.6	20.8	10.4	20.4	9.6
Three[a]	4.1	3.1	7.6	4.8	5.1	3.1	3.6	1.6
Four[a]	1.1	0.4	1.9	0.5	1.7	0.1	0.5	0

[a] Numbers represent percentage of animals recorded in the period.
[b] Heifers before calving were excluded.

Table 4
Estimated values (EV) and standard errors (SE) for five models of sole haemorrhage (SH), sole ulcer (SU), white line separation (WLS), double sole (DS) and white line abscess (WLA). The prevalence of the claw disorders was on cow level. Herd A and Parity 1 was used as the reference group.

		SH			SU			WLS			DS			WLA[a]		
		EV	SE	*P*	EV	SE	*P*	EV	SE	*P*	EV	SE	*P*	EV	SE	*P*
Intercept		-0.08	0.1		-4.42	0.26		-2.06	0.11		-3.22	0.15		-8.44	0.56	
Method	WLAM	-0.82	0.07	< 0.0001	-0.85	0.13	< 0.0001	-0.45	0.07	< 0.0001	-0.09	0.09	0.28	-0.53	0.26	0.04
Herd				0.04			< 0.0001			0.13			0.0001			0.15
	Herd B	0.08	0.12		0.61	0.23		0.22	0.12		0.49	0.13		-0.16	0.49	
	Herd C	0.27	0.12		0.56	0.23		-0.01	0.12		0.09	0.14		-0.43	0.51	
	Herd D	0.31	0.14		-1.18	0.33		-0.04	0.15		-0.07	0.17		-3.06	1.38	
Parity				< 0.0001			< 0.0001			< 0.0001			< 0.0001			< 0.0001
	2	0.12	0.07		0.72	0.15		0.7	0.09		0.59	0.11		1.21	0.32	
	3 +	0.38	0.08		1.86	0.16		1.31	0.09		1.39	0.11		1.87	0.38	
Days in milk (continuous)				0.002			< 0.002			0.04			0.43			0.29
	DIM	-3.88	2.58		-4.68	5.4		5.92	2.84		-4.91	3.87		-4.44	11.68	
	DIM^2	-10.35	3.02		-27.32	8.07		4.45	2.84		-3.1	4.96		-26.74	18.11	
Cow variance		1.5	–		4.74	–		1.22	–		0.87	–		21.48	–	

WLAM, White Line Atlas Method; DIM and DIM2, 'Days in milk' terms in the models as a quadratic effect of a continuous variable (DIMx + DIMx2 respectively).
[a] WLA had poor model fit and trimming method was not significant in all cross-validations.

Table 5
Odds ratios and corresponding 95%-confidence interval for claw horn disruption lesions recorded during claw trimming in dairy cows using the White Line Atlas Method versus the Danish Method after accounting for herd, parity and days in milk.

	Odds Ratio	95%-Confidence interval
Sole ulcer	0.42	0.33–0.54
Sole haemorrhage	0.44	0.38–0.50
White line abscess[a]	0.59	0.36–0.97
White line separation	0.64	0.55–0.74
Double sole	0.91	0.76–1.08

[a] Poor model fit and trimming method not significant in all cross-validations.

improved weight bearing on the lamella-laminar junctions. Increased load on the axial wall was considered to improve balance within the claws and improve balance between the lateral and medial claw. It is also hypothesised that the increased wear in the toe, facilitated by the breakover point, reduces the risk of overgrowth, and consequently decreases toe angle and increases weight on the heels.

Few studies have quantitatively evaluated the effect of the claw trimming method. In three intervention studies the effect of changing the modelling of the sole was evaluated. One study examined three groups of 120 cows over a 9-month period and the prevalence of CHDL was reduced in the group with a wide modelling of the sole compared to the normal modelling of the sole group and the untrimmed cows. The different lesions were not analysed separately in that study (Sadiq et al., 2021). Stoddard (2018) reported a protective effect of a larger modelling compared to normal modelling, on claw health in first lactation cows. The same effect was not found in older cows. Ouweltjes et al. (2009) adapted similar changes to the trimming method on 72 cows over a 3-month period but found no effect on prevalence of lesions and concluded that the sample size was too small to analyse data by lesion type.

The prevalence of WLA was significantly lower in the period with WLAM. However, since the prevalence of WLA was low (between 0% and 4.6%) the number of affected animals was too low for robust analysis. We chose a cautious interpretation of our results, taking into account cross-validation results and the large cow-cow variation in the analyses. The pathogenesis of WLA is suggested to be mechanical, whereby stones or other foreign material penetrate the soft horn of the white line (Shearer and van Amstel 2017a). When trimming using DAM where the same measurements are applied to all claws, little consideration is given to differences in claw and leg conformation between cows. With the WLAM each claw is trimmed specifically to the five individual anatomical characteristics. Based on the data collected in this study we cannot analyse the cause and effect of WLA.

Although the prevalence of DS was lower in two of the four herds with WLAM, this difference was not significant. This could indicate that DS is partly caused by other factors than housing, and is not affected by trimming to the same degree as other lesions. DS is defined as two or more layers of separated sole horn, and its pathogenesis has been described as a temporary stop in horn production due to separation in the dermal-epiderma junction (Ossent and Lischer, 1998). DS lesions can range from severe with a massive loss of sole horn, to a small area without soreness, and its aetiology is thought to be related to laminitis or pododermatitis (Ossent and Lischer, 1998).

The present study was a retrospective observational study, which has its limitations. Harris et al., (2006) stated that the most substantial limitations of these studies were a lack of internal validity and a lack of random assignment of the study groups on treatments. The lack of control of other unknown influential factors that could also have changed during the study period and improved CHDL would confound the results. However, by choosing herds by the criteria that no significant changes in key aspects of farm management had been made during a 4-year period, we have tried to mitigate this. The study also included just one trimmer, so we were unable to separate the potential effects of trimming methods from a general improvement in trimming quality, or of claw health unrelated to trimming simultaneous with the change in trimming method. However, the trimmer is a teacher in claw trimmer education in Denmark and therefore she would have had sufficient experience with both methods. It would have strengthened the results if multiple claw trimmers had collected data in multiple herds. At the same time, it is considered an advantage that the same trimmer used both methods within the herds to avoid confounding of trimmer and method effects.

The effect of trimming method needs to be further investigated. The present study contributes to the study of potential effects of claw trimming methods on claw health, and a randomised trial would be the next step to verify the results.

Conclusions

There was an association between trimming method and claw health. There was a significantly lower prevalence of SH, SU and WLS in cows trimmed with the White Line Atlas method compared to the Danish method. Further studies using a randomised experimental design with control groups are required to establish a possible causal relation the incidence of CHDL and trimming method.

Conflict of interest statement

None of the authors has any other financial or personal relationships that could inappropriately influence or bias the content of the paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tvjl.2022.105886.

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