UNIVERSITY OF COPENHAGEN
FACULTY OF LIFE SCIENCE, DEPARTMENT OF LARGE ANIMAL SCIENCE

Master Thesis

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A Comparison of the White Line Atlas Method and the Danish Method of Claw Trimming by Examining Claw horn Disruption Lesions. And an Investigation into the Effects of Claw Trimming with the White Line Atlas Method on the Rear Leg Rear View Score.

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Topic description:	This master thesis is developed as an observational study to study the effect of claw trimming with the White Line Atlas Method and the Danish Method on the claw horn disruption lesions. Furthermore, a study of the effect of the White Line Atlas Method on the rear leg rear view conformation was performed.
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ABBREVIATIONS

CHDL	Claw horn disruption lesions
SH	Sole haemorrhage
SU	Sole ulcer
WLD	White line disease
WLS	White line separation
WLA	White line abscess
DS	Double sole
CL	Claw trimmings
WLAM	White Line Atlas Method
DAM	Danish Method
RLRV	Rear leg rear view
BOP	Break over point
DIM	Days in milk
OR	Odds ratio
CI	Confidence interval

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ABSTRACT

Claw disorders are a major problem for health, welfare and economic loss in dairy cattle production. The objectives of this study were to investigate the effect of claw trimming with the White Line Atlas Method (**WLAM**) on the rear leg rear view (**RLRV**) score and claw horn disruption lesions (**CHDL**). The effect of the WLAM on the prevalence of claw disorders was compared to the prevalence of claw disorders when claw trimming with the Danish Method (**DAM**). This was investigated by analyzing data from four farms in Denmark over a four-year period, where the claw trimmings were performed with the WLAM over two years, and the DAM over the other two. In the end the data consisted of 3898 claw trimmings of 1080 different cows with the DAM and 3316 claw trimmings of 1027 different cows with the WLAM. The registrations of CHDL's included in the study, were sole hemorrhages (**SH**), sole ulcers (**SU**), white line abscesses (**WLA**), white line separations (**WLS**) and double soles (**DS**). The association between the claw trimming methods and the claw lesions was analyzed using a binominal logistic analysis. Our results showed a difference in the prevalence of SH, SU and WLS, with a lower prevalence during the period of trimming with the WLAM compared to trimming with

the DAM. No significant difference could be found when analyzing the prevalence of WLA and DS, when comparing the claw trimming methods.

The effect of WLAM on the RLRV score was investigated by scoring the RLRV of 34 heifers and 53 cows before and after claw trimming with the WLAM. It was analyzed as a Wilcoxon signed ranks test. Our results show that WLAM can increase the RLRV score and thereby correct the rear leg conformation to a less cow-hocked stance.

Key words

Hoof trimming, Sole hemorrhage, White Line Atlas Method, Hindleg conformation, Dairy cow

INTRODUCTION

Claw lesions in cattle are a big problem for health, welfare and economics around the world. Van der Waaij et al. (2005) and van der Linde et al. (2010) found that approximately 70 % of the Dutch dairy cattle had one or more claw lesions. Subclinical or untreated claw lesions had hidden but high costs. Claw lesions were assumed in dairy farming to be the third largest health cost after mastitis and fertility problems (Bruijnis et al., 2010; Verhoef, 2014) . Bruijnis et al. (2010) estimated an annual loss of 75 $ per cow with claw lesions.

A subclinical claw lesion is defined as a claw lesion with no lameness present. The economic losses were due to a drop in yield, longer calving intervals, veterinary costs, loss due to discarded milk, earlier culling, labor of the dairy farmer and claw trimmers (Bruijnis et al., 2010; Verhoef, 2014). This indicates that a reduction of the subclinical claw lesions such as sole hemorrhage (**SH**) can benefit the farmers economically. Amory et al. (2008) estimated that a cow with a sole ulcer (**SU**) lost 574 kg milk per lactation and a cow with white line disease (**WLD**) lost 369 kg milk per lactation. The drop in milk, when compared with the 5-month yield, could be seen 2 months before the discovery of the claw lesion.

There are two different types of claw disorders (I) infectious/skin-related disorders (e.g. digital dermatitis, interdigital dermatitis and interdigital phlegmone) and (II) claw horn disruption lesions

(**CHDL**) (e.g. double sole (**DS**), sole hemorrhage (**SH**), sole ulcer (**SU**) and white line disease (**WLD**)) (Bergsten, 2001; Nordic Cattle Genetic Evaluation, 2020; Verhoef, 2014).

The suspensory apparatus and the digital cushion support the weight of the cow (Räber et al., 2004). The suspensory apparatus has a significant amount of weight born by the lamellar-laminar junctions, where a failure of these junctions would separate the third phalanx from the claw capsule and the phalanx would begin to sink (Ossent & Lischer, 1998). Weakening of the lamellar-laminar junction of the third phalanx causes predisposition to SU, WLS and SH (Ossent & Lischer, 1998; Shearer & van Amstel, 2017b). Reduced suspensory support by the laminae for the third phalanx was by Tarlton et al. (2002), thought to lead to a greater load on the sole and thereby a greater risk of bruising (SH) the sole. Sole ulcers might occur, if other risk factors such as longer standing time on concrete flooring are present, when the suspensory apparatus is already weakened (Tarlton et al., 2002). The junction weakening is often caused by multifactorial risk factors such as hormonal activities peripartum, cow comfort, prolonged standing, horn overgrowth and claw conformation (Shearer & van Amstel, 2017b).

To my knowledge there are only a few studies investigating effect of claw trimming method on claw health. Manske et al. (2002) found that the prevalence of CHDL would be higher if there were no intervention of claw trimming. They investigated whether there was a difference in CHDL when trimming once or twice a year. A significant difference was found where trimming twice a year had a lower prevalence of CHDL. Sogstad et al. (2007) found that cows yielded more milk after claw trimming compared to before claw trimming. They speculated whether this could be a result of in-creased comfortable walking and standing after correction of claw shape and improvement of claw disorders. Studies found a smaller prevalence of SH and WLD when routine claw trimming of cows in tie stalls (Fjeldaas et al., 2006; Sogstad et al., 2005).

The claw trimming technique is important to ensure a good claw conformation where the third phalanx is parallel to the inside of the claw capsule and the lamellar-laminar junctions can support the biomechanical forces through the toe axis (Tarlton et al., 2002). If the claw trimming method supports the function of the suspensory apparatus and the biomechanical forces affecting the foot, we would expect a lower prevalence of SH, SU and WLS compared to other methods not considering this. Factors of claw trimming that we expect can contribute to change in CHDL prevalence, is horn overgrowth, claw conformation, frequency of claw trimming, timing of claw trimming within the lactational cycle and claw trimming method (Bergsten, 2001; Manske et al., 2002; Sogstad et al., 2005; Tarlton et al., 2002). In this study, the only factor changed was the method and it was assumed that the other factors were the same over the four-year period.

When a claw is overgrown in the toe, the animals' optimal toe angle is reduced. This forms a lever effect, causing extra weight distribution on the posterior part of the sole. In combination with an unyielding surface, such as concrete flooring, it will strain the deep flexor tendon of the third phalanx. This could increase contusion of the corium, resulting in development of SH and SU. The Danish Method (**DAM**) of claw trimming focuses on improving the toe angle by trimming the sole in the anterior part of the claw. All trimmings are performed from the sole surface. This trimming technique probably results in early overgrowth of the toe due to the limited wear of the toe. However, the cause-effect relation of the trimming methods has to my knowledge not been investigated.

The purpose of claw trimming is to retain or re-establish the normal function of the claw by restoring correct weight-bearing and trimming overgrown horn (van Amstel et al., 2002). The result of incorrect claw trimming could be too thin soles, which reduces the resistance for contusion of the corium and thereby results in SH (Bergsten, 2001; Shearer & van Amstel, 2017b; van Amstel et al., 2002).

Claw trimming can be both preventive and curative (Somers et al., 2003). When WLD is detected early, corrective trimming is curative (Shearer & van Amstel, 2017a).

In Denmark the most commonly used claw trimming method is the DAM. The focus of the DAM is to (I) ensure that the angle of the toe is 45-52° (Figure 1).

Figure 1: A claw trimmed with the Danish Method of claw trimming. The most important step is to ensure that the angle is between 45-52°, which is shown with the black angle.

<u>Principles of the Danish Method (**DAM**)</u>

I. Toe angle to 45-52°
II. The axis of the toe should be straight
III. Heels at the same height
IV. Sole 8-10 mm thick
V. Modelling of the typical sole ulcer site

(Capion, 2018)

The cow’s leg conformation should be considered to assess how much of the angle can be corrected. If the angle is very diverted or the claw overgrown, assessment is needed to decide whether to correct the angle at once, or gradually over more trimmings. The axis of the toe (II) should ideally be straight and (III) the heels should be at the same height. The sole (IV) is trimmed to be 8-10 mm thick and (V) the sole should be modelled to relieve pressure on the typical sole ulcer site. Usually one would try not to trim too much of the small claw (the front lateral claw and the rear medial claw) (Nynne Capion, 2018). When trimming with the same measurements to all claws, no considerations are made to the difference in claw and leg conformation between the cows.

The claw trimmers White and Daniel (2017) combined their experience and made a document describing the WLAM. The WLAM focuses on the animal’s daily routines; stand, move, lie down and get up, thereby providing a balanced claw trimming. An ideal balanced claw is one where all the biomechanical forces are in balance. Five bio-markers provided by almost every animal can be used to guide the claw trimmers towards a balanced claw. The five bio-markers are the heel fulcrum, the white line of the claw, normal sole thickness, the pressure ridge and the break over point (**BOP**).

Each claw is trimmed specifically to the five individual bio-markers by identifying the claws of the foot consisting of a stabilizer and stress claw. The stabilizer claw (front lateral and rear medial) are named by their most consistent health results whereas the stress claws (medial front and lateral rear) suffer the most CHDL. The WLAM consists of eight steps (White and Daniel, 2017). Step one (I) is to evaluate stance and movement when the cow is on its feet. The front and hind legs should be evaluated in two separate profiles. The decision process (II) should be chosen by reviewing the BOP, which is defined as the point of the claw where the cow in its walk rolls over the toe and leaves the ground. It is characterized as a negative, neutral or a positive BOP, depending on the cow's ability to regulate the length of the toe on its own. If there is a negative BOP, no wear has been applied to the toe and the toe will be overgrown. The decision process at a negative BOP is to choose a salvage trim, which focuses on correcting as much of the claw conformation as possible without worsening it. A subsequent trimming might be necessary to regain a proper balanced claw conformation. If the claw is not overgrown and either has a neutral or positive BOP, a normal trim is chosen to leave the claws in a functional shape with comfortable weight distribution.

<u>White Line Atlas Method 8 steps</u>

I. Evaluate stance and movement
II. Choose decision process
III. Establish the heel fulcrum of the stabilizer claw and the stress claw
IV. Cut from the heel fulcrum level of the stress claw through the pressure ridge and repeat on the stabilizer claw
V. Cut toe just in front of the break over point
VI. Trim to optimal sole thickness
VII. Reassess heel and toe length
VIII. Model sole crushing area

(White & Daniel, 2017)

The claw is divided into different zones as presented in Figure 2.

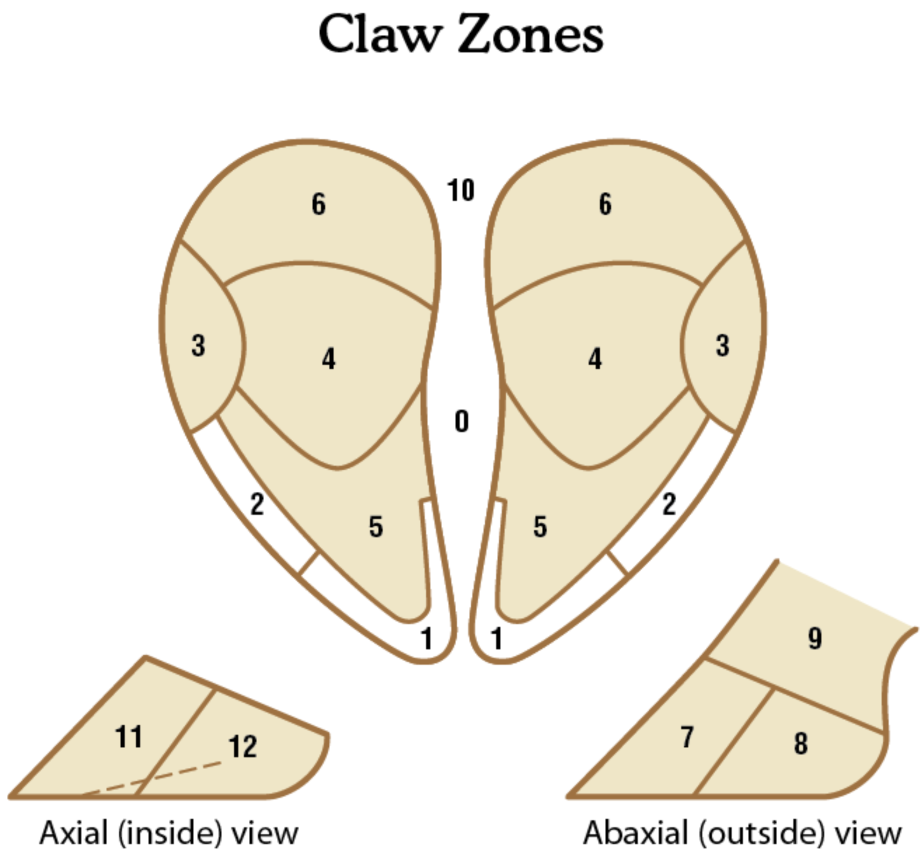


Figure 2: The claw zones are used to describe zones of the claw. The claw trimming method the White Line Atlas Method uses the claw zones as indicators where to trim (Zinpro Corporation, 2008)

The zones in Figure 2 are used as indicators where to trim. The heel fulcrum (Figure 3) can be established (III). The heel fulcrum in Figure 3 is from the front foot where the heel fulcrum emanates from the bottom of the flexor tendon, intersecting the hair line.

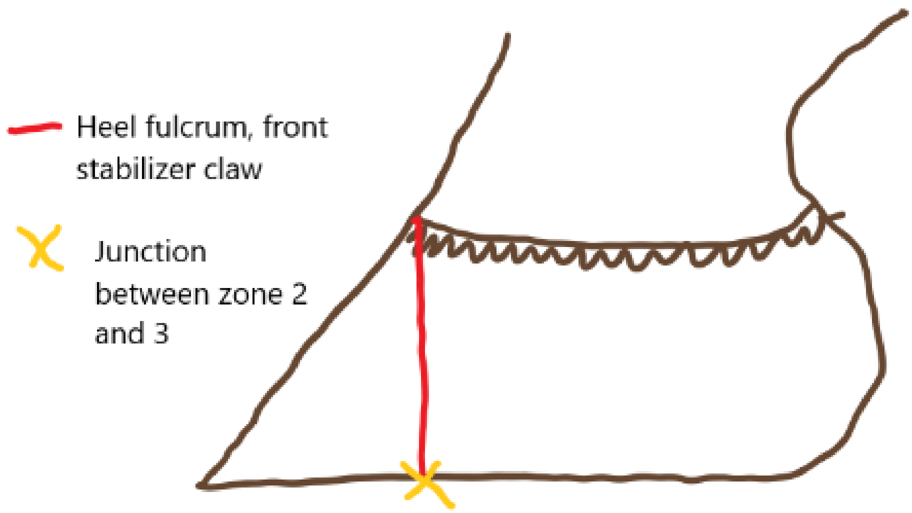


Figure 3: The heel fulcrum is one of the five bio-markers from the White Line Atlas Method of claw trimming. It extends from the hairline of the front stabilizer (lateral) claw and around the claw. It should meet at the junction between zone 2 and 3 and it then continues under the sole towards the beginning of the axial groove (White & Daniel, 2017).

The heel fulcrum proceeds as Figure 3 presents down the side of the claw and continues in a straight line under the sole from the stabilizer claw (front lateral and hind medial) to the stress claw (front medial and hind lateral). Figure 4 presents the pressure ridge, which is the strongest point of the claw. Figure 4 also presents that the heel fulcrum of the rear foot emanates from the top of the flexor tendons.

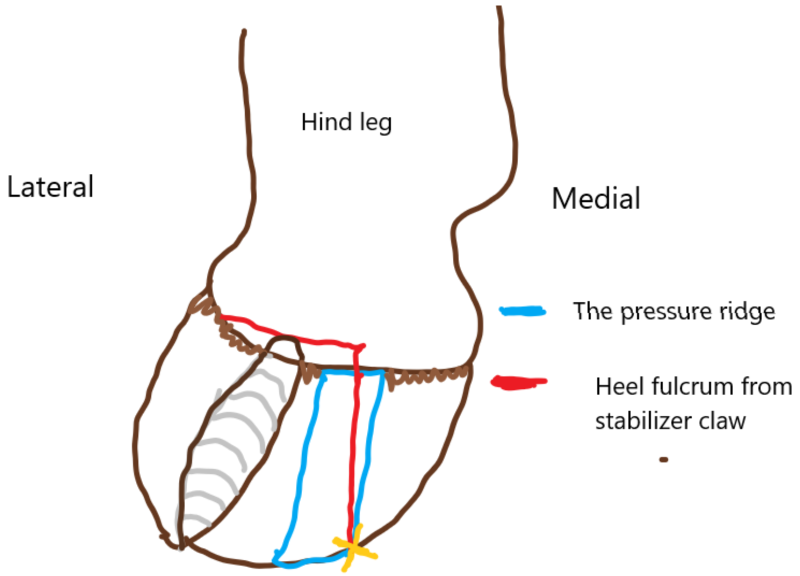


Figure 4: The pressure ridge is one of the five bio-markers used when trimming claws with the White Line Atlas Method. It is the strongest point of the claw. It is present on all claws on the abaxial wall of the claw. In a stable foot the heel fulcrum should intersect at the back of the pressure ridge as shown in this figure with the yellow cross.

Figure 5: A claw trimmed with the White Line Atlas Method. The black line presents the continuance of the heel fulcrum between zone 2 and 3. The heel fulcrum is one of the five bio-markers used when claw trimming with the White Line Atlas Method.

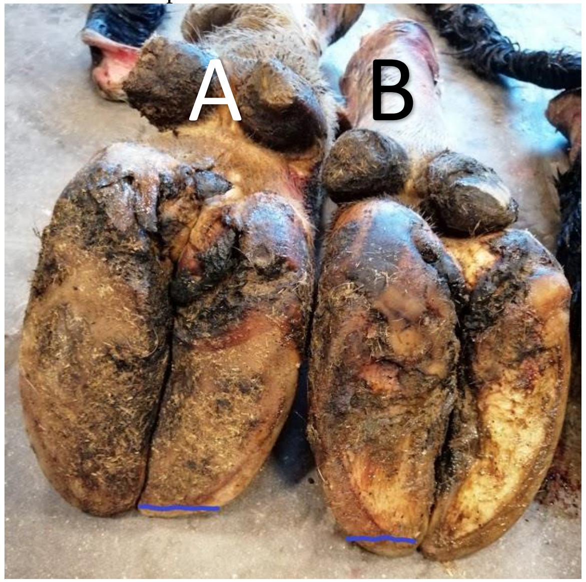
A line on the stress claw is cut from the level of the heel fulcrum through the pressure ridge at zone 2 (Figure 2 and 4). This exposes the white line in zones 1 and 2 (Figure 2). Figure 3 presents the heel fulcrum from the side and Figure 5 shows the continuance of the heel fulcrum on the sole surface of the claw. The stabilizer claw (IV) is not trimmed beyond the line of the heel fulcrum on claws with a positive or neutral BOP, but it might be necessary to trim in zone 3 on the stress claw to achieve balance. In claws with a negative BOP (overgrown) it might be necessary to trim zone 3 on the stabilizer claw to achieve balance. Next (V) is to cut the toe length just ahead of the BOP in claws with a neutral BOP or to the outer third of zone 1 in claws with a negative BOP (Figure 2). This step reveals how much sole can be trimmed. The determination of the optimal sole thickness ensures that the sole can be trimmed (VI) from the heel fulcrum of the stress claw and through the pressure ridge without trimming the sole too thin. Step VI is repeated for the stabilizer claw. The next step (VII) reassesses the level of the heel and the toe length. Both claws should be shortened to the BOP. The BOP is presented as a blue lines in Table 1 on the untrimmed claws (White & Daniel, 2017).

The final step (VIII) is to relieve pressure on the typical sole ulcer site by modelling a cut resembling a tablespoon which slopes from the sole at zone 4 towards the axial groove (White & Daniel, 2017).

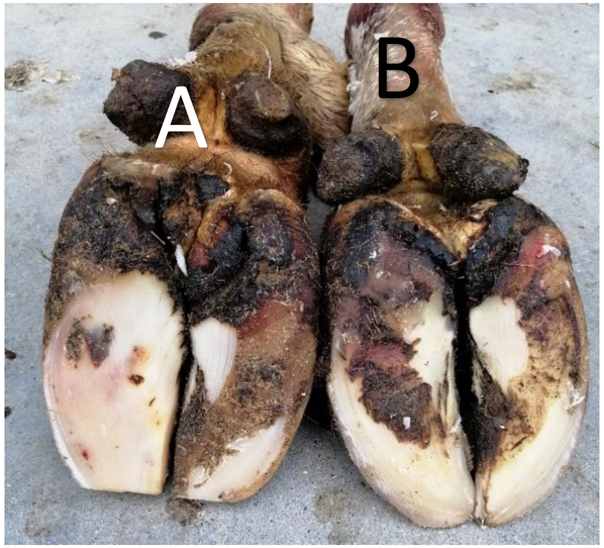
Table 1 presents the difference between the outcome after claw trimming with the two claw trimming methods.

*Table 1: The difference of the outcome between the two claw trimming methods the White Line Atlas method (**WLAM**) and the Danish Method (**DAM**) presented in pictures.*

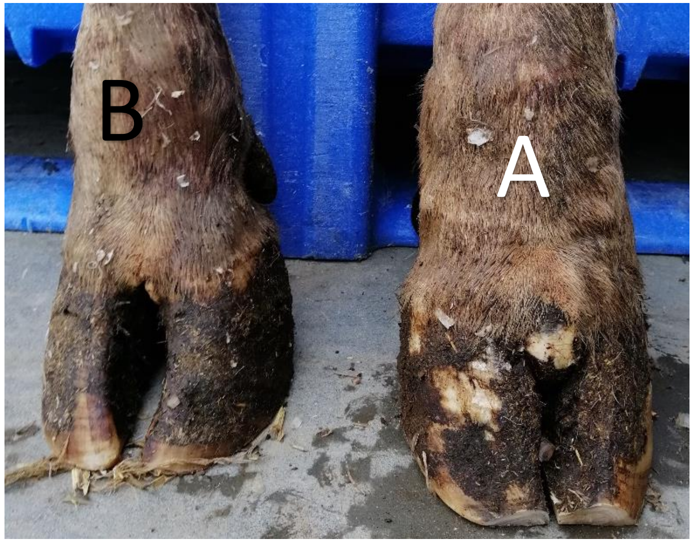
Claw A and B before trimming. The blue lines present the break-over points.



Claw A trimmed with the WLAM and claw B trimmed with the DAM.



Claw A trimmed with WLAM and claw B trimmed with DAM.



Claw A trimmed with WLAM

Claw B trimmed with DAM

In Table 1, two asymmetric claws from a slaughterhouse are presented. Claw A was trimmed with the WLAM and claw B was trimmed with the DAM. The most noticeable differences are the trimming of the toes and the angle of the claw. The WLAM trims to the BOP, and the DAM does not trim the toe. The DAM focuses mostly on the angle and not the conformation of each individual claw. It is also presented that the DAM mostly trims the anterior part of the sole, while the WLAM trims up to zone 3.

To my knowledge this is the first study to compare the WLAM with the DAM.

Leg conformation theory

Capion et al. (2008) found that 81 % of Danish Holstein heifers had cow-hocked rear leg conformation, defined as wide-based stance, hocks together and lateral rotation of the feet.

When a cow abducts her rear leg, the toes twist out in a cow-hocked position. When assuming cow-hocked position the medial claw bears weight on the wall, leaving the sole less loaded. The weight distribution of the lateral claw moves from the outer wall to the sole which predisposes for CHDL (Bergsten, 2001). The lateral hind claw is the one most affected with claw disorders, especially SU (Nuss et al., 2019; Shearer & van Amstel, 2017a).

Nuss et al. (2020) indicated that there was no significant difference between the weight distribution on the lateral or medial claw of the hind legs before trimming when comparing cows with a cow-hocked stance and with a parallel stance. The heel of the lateral claws bore 51 % and the sole of the lateral claws bore 17 % of the entire weight of the limb before trimming. They trimmed the claws with the functional trimming method, where the focus is to make the claw length 7.5-8 cm long. After trimming, the zone of the sole of the lateral claw bore 26 % in the cow-hocked cows and 19 % in cows with parallel hind legs. They concluded that trimming of cow-hocked cows resulted in a shift of the weight distribution from the heel of the lateral claw to the sole (Nuss et al., 2020). A shift of weight to the sole may increase contusion of the sole and increase the amount of SH. Nuss et al.

(2020) did not investigate whether the functional trimming method changes the rear leg rear view (**RLRV**) conformation. The rear leg rear view score from Nordic Cattle Genetic Evaluation is presented by Figure 6.

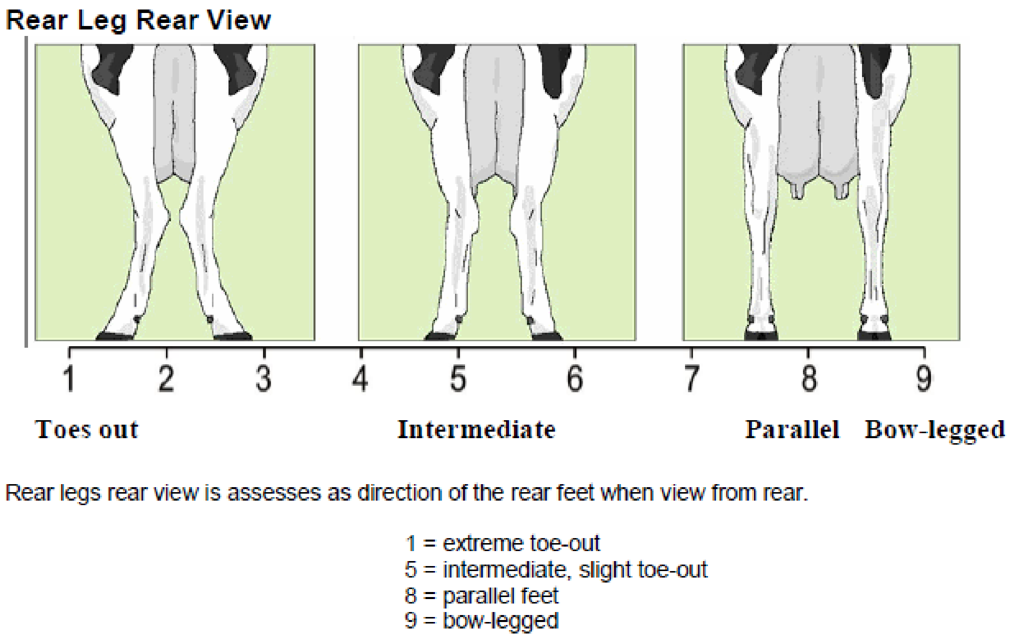


Figure 6: Rear Leg Rear View score from International Committee for Animal Recording approved standard traits (International Committee for Animal Recording, 2015). The score of 8 is the most ideal rear leg rear view conformation.

Figure 6 demonstrates the different scores. The smaller the score the more cow-legged a RLRV conformation. The score of 8 is the most ideal score with parallel legs and the score of 9 is a bow-legged RLRV conformation. The cow-hocked leg conformation seemed to lead to increased weight distribution to the lateral hind claw, which could lead to asymmetric claws as a result of claw lesions, overload and overgrowth (Capion et al., 2008). Cow-hocked leg conformation has by Boettcher et al. (1998) been associated with increased lameness. Low to moderate genetic correlations between RLRV score and CHDL have been found, where the cow-hocked cows had increased risk of CHDL (Ødegård et al., 2014).

To my knowledge this is the first study to examine whether claw trimming changes the hind leg conformation of dairy cows.

The overall aim of the study was to evaluate the prevalence of CHDL in dairy cows trimmed using the DAM compared to the WLAM and evaluate the effect of WLAM on the hind leg conformation.

The objective of Experiment 1 was to compare the claw health registrations of SH, SU, WLS, WLA and DS from cows trimmed on four dairy herds over the past period of four years. Two years of claw trimming registrations with the DAM and two years of claw trimming registrations with the WLAM in the same herds were used. The CHDL registrations were used as a measure of the preventive effect of claw trimming and was compared between the two methods. The hypothesis was that cows trimmed with WLAM would have a lower prevalence of CHDL compared to cows trimmed with the DAM.

The objective of Experiment 2 was to compare the RLRV score of heifers, 1st and 2nd lactation cows in three dairy herds before and after trimming with the WLAM. The hypothesis was that the WLAM could increase the RLRV score.

MATERIALS AND METHODS

A team consisting of two claw trimmers was chosen as a result of knowledge of their consistent and thorough registration of claw disorders and them being some of the front-runners in Denmark for the WLAM. One claw trimmer trims the left side of the cow and the other the right side. If bandages or shoes are needed the person on the left will trim both hind legs and the person on the right will bandage/shoe the claw(s). The person on the right registers the claw disorders from both sides. When I overlooked them working at herd A, B and C, both trimmers registered consistently and if one was in doubt, they would confer with the other before concluding anything. The claw trimmers have trimmed with the WLAM since October 2018 and before this they trimmed with the DAM. The claw trimming registrations were extracted from the Danish Dairy Management System from all 4 farms dating from the 1^{st} of August 2016 to the 15^{th} of September 2020.

Four conventional herds (Table 2) were selected, where the claw trimming was performed by the selected claw trimmers over the past four years. The herds were further selected for having no significant changes during the past 4 years such as flooring, bedding, management or trimming routines. Herd D was sold in May 2020, which means there are no registrations from this herd from May 2020 to September 2020. Table 2 presents the size of the herds, the breed, the flooring, and the barn- and milking system.

Table 2: Information about size, breed, barn system, milking system and flooring within the 4 selected herds used for data collection in the present study.

	Herd A	Herd B	Herd C	Herd D
Year cows	205.2	202.7	196.8	90.84
Breed	Red Danish dairy breed	Red Danish dairy breed	Red Danish dairy breed	Danish Holstein
Barn system	Free stall	Free stall	Free stall	Free stall
Milking system	Milking parlor	Milking parlor.	Automatic milking system	Milking parlor
Flooring	Full concrete floor-ing	Slatted flooring	Slatted flooring	Slatted flooring

A noticeable difference between the herds in Table 2, is the size of herd D, which is less than half of the others. Another difference is that herd A, B and C had Red Danish dairy breed whilst herd D had Danish Holsteins. Neither the size nor breed can therefore be separated as an influencing factor from the management of herd D, when cross-validating.

Herd A to C were still functioning dairy productions and were therefore selected to perform Experiment 2 on. In Experiment 2, all heifers from herd C and all 1^{st} and 2^{nd} calf cows from herd A and B being claw trimmed in September 2020 were included in the study.

Experiment 1

To test the hypothesis, the categories CHR number (Central husbandry animal registration), CKR number (Animal registration number), trim-date, trim registrations, claw diseases, localization (legs), severity score (mild or severe for SU and SH), claw trimmers, date of birth, expected calving date and lactation number were extracted to a dataset consisting of 26.554 observations divided over 1665 cows and heifers. The data was analyzed using R version 4.0.3 (R Core Team, 2020).

The chosen claw trimmers accounted for 26.363 of the observations. The remaining 191 observations were removed to eliminate bias from other claw trimmer's registrations, since their method of trimming was unknown.

Skin-related claw disorders were removed leaving the five CHDLs; SH, SU, DS, WLA and WLS. All lesions included leg registrations, except one. The claw trimming of the one cow missing this information was excluded. The registrations could have combinations where 1, 2, 3 or 4 legs were affected with the lesions.

The days in milk (**DIM**) at claw trimming was calculated as the days between calving and the trim-dates. Since the model conflicted with the heifers' DIM at 0 the 268 trimmings of heifers were removed from the dataset. The cows' ages were grouped into 1, 2 and +3 according to their lactation number.

The trim-dates were overlooked and any dates with less than 20 trimmings were removed. These trimmings did not include more than 15 cows and therefore they were considered an emergency trim focusing on acute symptoms. The claw trimming would then be curative and not preventive in such a case. The dates were further divided by dates. The use of claw trimming with the DAM during the 1st of Aug 2016 to 30th of Sep 2018. A period of three months was excluded as a transition period for the claw trimmers to gain some experience with the WLAM. Claw trimming with the WLAM went on from the 1st of Jan 2019 to 15th of Sep 2020.

In the end the dataset consisted of 3898 claw trimmings of 1080 different cows with the DAM and 3316 claw trimmings of 1027 different cows with the WLAM. The whole dataset included 1623 different cows which means 484 cows were trimmed with both methods.

The Statistical Model

The analyses were made as a binominal logistic analysis, where I let Y_{ij} be the result of either SH, SU, DS, WLA or WLS in cows (j) and trimmings (i), which can take the values 0 and 1.

Then Y_{ij} is a realization of the random variable Y_{ij} where $Y_{ij} \sim$ Binominal$(1,\pi_{ij})$ and $\pi_{ij} = Pr(y_{ij}=1)$.

Giving the model to be analyzed:

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

Where i = trimmings; j = the cows

β_1 = Coefficient for the method (WLAM); β_2 = Coefficient for herd

β_3 = Coefficient for lactation group; β_4 = Coefficient for the DIM

β_5 = Coefficient for DIM squared

$\beta_{0j} = \beta_0 + u_{0j}$ and $u_{0j} \sim N(0, \sigma^2_{u0})$ where u0j is the contribution of each cow j.

A cross-validation was performed where the dataset was randomly reduced by 20 % 5 times per claw disorder. The statistical model was then performed on the new randomly reduced datasets.

To evaluate the effect of the herds on the model a leave-one-site-out cross validation were performed. The model was run 4 times, where on herd was excluded each time.

Experiment 2

Experiment 2 was performed by scoring the heifers and cows RLRV conformation before and after trimming with the WLAM. The scoring was performed by using the Nordic Cattle Genetic Evaluation Rear Leg Rear View score 1-9 (Figure 6).

To ensure consistency in scoring authors ESC and NC scored the heifers at herd C before trimming together, and the rest of the scoring was performed by author ESC. To further present how we scored, Table 3 has been developed with pictures from the herds.

Table 3: The rear leg rear view scoring system performed by author ESC. There were no scorings of 1,2 and 9 therefore they are not included in this table. The scorings were performed in herd A, B and C before and after claw trimming with the White Line Atlas Method. There were no good pictures taken of the score 7 from behind, therefore one should focus on the hind legs whilst viewing the picture of score 7.

Score 3	**Score 4**	**Score 5**
		
Score 6	**Score 7**	**Score 8**
	 Focus on hindlegs	

Table 3 demonstrates the differences in the scorings made by ESC in the three herds A, B and C. Score 8 is a bit unclear but the best picture which was taken. The left leg is a bit twisted in this picture, so the focus should be on the right leg.

The scorings were performed two days before the claw trimming with the WLAM, the claw trimming was overseen by author ESC and then the score was retaken a week after the trimming. The second scores were collected blindly, where no knowledge to the first scoring was available. The scorings were excluded from the dataset, when the rear leg conformation of the legs from the same cow, was so different between the two legs, that not only one score could be given. If the cows had a locomotion score >3, the scores were excluded as a result of them not supporting themselves correctly. In the end the data consisted of 34 heifers and 53 cows from the herds A, B and C.

The two observations on the same heifers or cows produce a dataset that needs to be analyzed as paired observations, as a result of it being repeated observations of the same object. Therefore, it was analyzed with a Wilcoxon signed-rank test, which analyzes whether the corresponding data populations distributions are identical.

The null hypothesis was; There is no difference between the RLRV score before and after claw trimming with the WLAM. This was tested at a 0.95 significance level.

$$H_0: P(X_{Score\ before} > X_{Score\ after} = 0.5)$$

Testing the null hypothesis; if the score before has a 50 % chance of being larger than the score after.

RESULTS

Experiment 1

In Table 4 the distribution of the claw disorders of cows trimmed with the two methods are presented. It is further divided into the different herds.

*Table 4: Sole hemorrhage (**SH**), Sole ulcer (**SU**), double sole (**DS**), white line abscess (**WLA**), white line separation (**WLS**) and claw trimmings (**CT**) within the different herds used for data collection in this study. The disorders are in percentages cows affected out of the number of CT and further categorized in the two claw trimming methods; the Danish Method (**DAM**) and the White Line Atlas Method (**WLAM**).*

	Herd A		Herd B		Herd C		Herd D	
	DAM	WLAM	DAM	WLAM	DAM	WLAM	DAM	WLAM
CT	772	967	1225	990	1211	1013	690	346
SH (%)	55.3	40.1	59.2	43.2	65.5	41.5	61.6	43.6
SU (%)	13.6	7.8	19.6	7.8	14.5	7.5	6.2	0.9
DS (%)	10.5	11.1	17.6	13.5	11.1	8.9	9.4	9.5
WLA (%)	2.5	1.6	4.6	3.6	2.9	1.8	0.9	0
WLS (%)	24.2	20.4	29.8	22.5	24.1	16.6	25.6	12.7

Table 4 provides an overview of the registrations. Herd D had a very low prevalence of WLA and SU when trimming with DAM compared to the other herds. The prevalence of WLA and SU in herd D were still less when trimming with WLAM even though the prevalence was so little when trimming with the DAM. In herd B, C and D the SU was reduced by more than half when trimming with the WLAM compared to the DAM. Herd D only registered 348 trimmings with the WLAM. Table 4 also presents the prevalence of DS, where there is a higher prevalence when the WLAM was used in herd A and D and a higher prevalence of DS when trimming with the DAM in herd B and C. In general, the prevalence of DS does not change a lot between neither herds nor methods.

The registration of having a claw disorder on all four legs compared to only one leg was considered more severe. In Table 5, the distribution of the claw disorders on cow level compared to leg level is presented. The claw trimmings at leg level are the cow level claw trimmings multiplied by four.

*Table 5: Distribution of sole hemorrhage (**SH**), sole ulcer (**SU**), double sole (**DS**), white line abscess (**WLA**) and white line separation (**WLS**). It is further divided into parity and the percentage of cows and amount of legs affected. The total cows with lesions out of cows trimmed is calculated (total cow level) in percentage. The leg level claw trimmings are the cow level claw trimmings multiplied by 4. The total number of legs affected out of the total amount of legs trimmed is calculated (leg level) in percentage.*

Parity		1	2	+3
Claw trimmings	Cow level	2949	2056	2209
	Leg level	11796	8224	8836
Sole hemorrhage (SH) (%)	Cow level	49.6	49.7	57.7
	Leg level	24.7	23.6	26.3
Sole ulcer (SU) (%)	Cow level	5.9	9.9	18.8
	Leg level	1.8	2.8	5.7
Double sole (DS) (%)	Cow level	6.3	10.8	20.5
	Leg level	1.9	3.1	5.9
White line abscess (WLA) (%)	Cow level	1.5	2.7	3.9
	Leg level	0.4	0.7	0.9
White line separation (WLS) (%)	Cow level	14.3	23.3	33.9
	Leg level	4.8	7.6	11.1

In Table 5, the distribution over parity and leg level is presented. The closer the percentage of the leg level is to the cow level, the more legs are in general affected. In Table 5, most of the leg level percentages are less than 50 % of the cow level percentages for the same claw disorder and age. This means that the cows at one trimming on average had fewer than two legs affected with a specific CHDL and age. The SH scores had the highest leg level percentages compared to the cow level percentages, where there on average were almost two legs affected per claw trimming. Due to the low prevalence of leg-level in Table 5, the statistical analyses were made on cow-level. It was assumed to be better for the welfare of the cows to be completely free of claw disorders.

Table 6 presents the parameter estimates, standard errors and p-values for the five models for the different claw disorders SH, SU, WLS, WLA and DS.

*Table 6: The statistical outcome from the models. The data was registered during claw trimming of dairy cows in four herds. The model was performed for sole hemorrhage (**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. Parameter estimate, standard error (**SE**) and P-value for method, herd parity and days in milk (**DIM**). The methods compared were the prevalence of the claw disorders when trimming with the Danish claw trimming Method (the intercept) and the White Line Atlas Method (**WLAM**).*

			SH			**SU**			**WLS**			**DS**			**WLA**	
		Estimate	**SE**	**P-value**	**Estimate**	**SE**	**P-value**	**Estimate**	**SE**	**P-value**	**Estimate**	**SE**	**P-value**	**Estimate**	**SE**	**P-value**
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
	Herd2	0.08	0.12		0.61	0.23		0.22	0.12		0.49	0.13		-0.16	0.49	
	Herd3	0.27	0.12		0.56	0.23		-0.01	0.12		0.09	0.14		-0.43	0.51	
	Herd4	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	
Lactation stage				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	1.22		4.74	2.18		1.22	1.1		0.87	0.93		26.74	5.17	

Table 6 demonstrates that the p-values for SH, SU, WLS, and WLA is <0.05 for the method. This means that there is a significant difference of the prevalence of these claw disorders when comparing the two methods. The p-value of DS and the methods are >0.05, which means the model cannot find a significant difference between the prevalence of DS within the two methods.

Table 7 presents the odds ratio (**OR**) and the confidence interval (**CI**) to the OR for the models performed for SH, SU, WLS, WLA and DS.

*Table 7: Odds ratio (**OR**) of claw horn disruption lesions registered during claw trimming in dairy cows using either the Danish claw trimming method (**DAM**) versus the White Line Atlas Method (**WLAM**) and the confidence interval to the OR.*

	Parameter tested	Odds Ratio	Confidence Interval
Sole ulcer	DAM vs WLAM	0.42	0.33-0.54
Sole hemorrhage	DAM vs WLAM	0.44	0.38-0.5
White line abscess	DAM vs WLAM	0.59	0.36-0.97
White line separation	DAM vs WLAM	0.64	0.55-0.74
Double sole	DAM vs WLAM	0.91	0.76-1.08

If the CI to the OR includes 1, then no conclusion can be made whether there is a difference between the prevalence of the claw disorders when trimming with the two methods. Table 7 demonstrates that the SH, SU, WLS and WLA have a CI to the OR that does not include 1. However, WLA has a wide CI close to 1, which gives good precautions to check the results in a cross-validation. The CI to the OR of DS includes 1 and therefore the prevalence could be either the same or different between the two methods. The ORs for SH, SU, WLS and WLA are less than 1, which indicates that these claw disorders are less prevalent in the period of trimming with the WLAM compared to the period of trimming with the DAM.

To further test the models' significance, a cross-validation was performed. The dataset was randomly reduced with 20 % of the cows, 5 times for each CHDL. The ORs calculated for the WLAM vs the DAM from these new analyses are presented in Table 8.

*Table 8: Odds ratio (**OR**) for random samples (**RS**) where 20 % of the cows were randomly excluded from the dataset of claw horn disruption lesions (**CHDL**) registered during claw trimming in dairy cows. This was performed to investigate cross-validation. The OR is calculated for the methods (the Danish claw trimming method and the White Line Atlas Method) and the different CHDLs.*

	Sole ulcer	Sole hemorrhage	White line abscess	White line separation	Double sole
RS 1	0.42	0.43	0.85°	0.65	0.98°
RS 2	0.36	0.45	0.46	0.67	0.96°
RS 3	0.48	0.44	0.8°	0.69	0.89°
RS 4	0.45	0.46	0.8°	0.67	0.9°
RS 5	0.44	0.44	0.77°	0.63	0.95°
Interval of sample OR	0.36-0.48	0.43-0.46	0.46-0.85	0.63-0.69	0.89-0.98

° These OR's confidence intervals included 1.

Table 8 demonstrates whether the new ORs are significant. The CI to the OR of SH, SU and WLS does not in any of the random sample models include 1. This means that even with randomly reducing the dataset by 20 % of the cows, there is still a difference between the prevalence of SH, SU and WLS between the two methods. All 5 samples for DS still include 1 in the CI to the OR, which is conclusive with the first model and indicates that no significant difference can be found between the prevalence of DS when trimming with the two methods. The random sample 2 of WLA was the only one of the WLA models, where the CI to the OR did not include 1. As a result of these new ORs, no significant difference between the prevalence of WLA and the two trimming methods can be concluded.

Further on herd influence was investigated, by performing a leave-one-site-out cross-validation. This was performed on herd level and the OR was processed in the same way as the random sample removal. Table 9 presents the leave-one-site-out cross validation calculations of the ORs

*Table 9: The dataset used data from 4 herds where the claw horn disruption lesions were registered during claw trimming of dairy cows. The odds ratios (**OR**) were calculated for the removal of 1 herd at the time, to investigate the cross-validation between the herds and the methods. The OR is calculated by comparing method (the Danish Method and the White Line Atlas Method) of each claw disorder.*

Herd removed	Sole ulcer	Sole hemorrhage	White line abscess	White line separation	Double sole
Herd A	0.39	0.41	0.74°	0.58	0.87°
Herd B	0.46	0.41	0.54	0.61	0.99°
Herd C	0.4	0.49	0.77°	0.68	0.91°
Herd D	0.44	0.45	0.8°	0.67	0.89°
Interval of farm OR	0.39-0.46	0.41-0.49	0.54-0.8	0.58-0.68	0.87-0.99

° These OR's confidence intervals included 1.

Table 9 illustrates that SH, SU and WLS are within the acceptable range of CI to the OR. The removal of herd B when analyzing WLA provided an acceptable OR with an acceptable CI. This could indicate that herd B influences the results of the WLA. However, since the random sample test did not validate the WLA result, this was not investigated further. The ORs of DS all included 1 in their CI, therefore no herd had a significant influence on the results of the first model and no significant difference can be found.

Experiment 2

The RLRV differed from before and after trimming. The distribution of scores of the 34 heifers and 53 cows can be seen in Table 9.

Table 9: The distribution of the rear leg rear view score (1-9) in percentages of heifers/cows with the different scores before and after claw trimming with the White Line Atlas Method.

Score	1	2	3	4	5	6	7	8	9
Heifers before trimming (%)	0	0	11.8	20.6	38.2	17.6	8.8	2.9	0
Heifers after trimming (%)	0	0	2.9	14.7	29.4	41.2	8.8	2.9	0
Cows before trimming (%)	0	0	1.9	32	44.2	18.8	3.8	0	0
Cows after trimming	0	0	0	9.4	35.8	33.9	18.9	1.9	0

Table 9 demonstrates that there was a difference in the prevalence of the scores before and after trimming. It does not present how big a difference the same animals had in the RLRV score. This is presented in Figure 7.

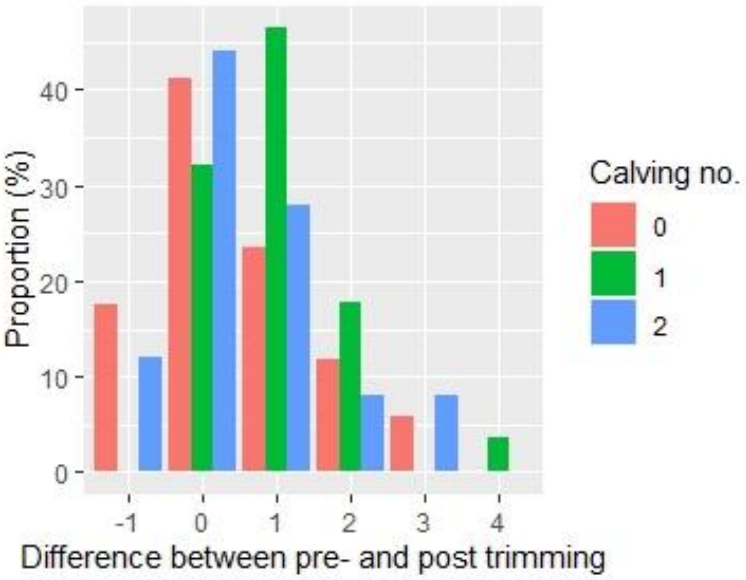


Figure 7: The difference in the rear leg rear view score before and after trimming. The difference was calculated by the score after trimming minus the score before trimming. The amount of heifers/cows with a certain difference was calculated in percentage. This is categorized in calving numbers where 0 is heifers.

Figure 7 illustrates how many heifers/cows had a better, same or worse score before and after claw trimming. The scores only got worse by one, but they got better by increasing the score by 1-4. However, 34 animals did not change their scores by trimming with the WLAM.

The results of the Wilcoxon signed-ranks test are presented in Table 10.

Table 10: The results of the Wilcoxon signed-ranks test performed on Experiment 2 where the rear leg rear view score were scored before and after claw trimming with the White Line Atlas Method in the dairy herds A, B and C. The heifers' data was collected at herd C and the cows' data was collected at herd A and B.

Wilcoxon signed-ranks test	Heifers	1st and 2nd lactation cows
p-value	0.02	< 0.0001
W-value	45	36

Both the heifers and cows had a p-value of < 0.05 which means that the null-hypothesis at a 95 % significant level can be rejected. This indicates that there was a significant difference between the difference in the scores before and after trimming with the WLAM. In general, there was a better score after trimming with the WLAM.

DISCUSSION

Experiment 1

A pre-post study such as this one does not have control over other elements that changes during the period. There has for many years been focus on better claw health in cattle in Denmark. This study cannot predict whether the claw trimming method or any other changes over the period of this study, could have had an influence on the decreased in CHDL. The bias was assumed to be reduced by choosing the herds by the criteria that no significant changes must have been made during the past 4 years. However, small changes in the herds with influence on claw health are unknown.

The claw health and claw trimming are well connected. 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 & Lischer, 1998; Shearer & van Amstel, 2017b).

Mostly, it was expected to find a difference between SH, SU and WLS between the two methods, as a result of the knowledge of the weight bearing on the lamella-laminar junctions and the importance of them. The pathogenesis of WLA can be mechanical where stones or other foreign material on especially on cattle walkways can penetrate the soft horn of the white line (Shearer & van Amstel, 2017a). This might be why there is no significant difference between WLA using the DAM and the WLAM. Another reason could be that the sample size of WLA could be too small to have a significant OR when cross-validating.

Fejldaas et al. (2006) did not find any correlation between routine trimming and fewer hemorrhages, which they indicated could be because Norwegian claw trimmers tend to trim too much of the dorsal and axial wall, making the sole too thin. This indicates that the claw trimming method could be an important factor in reducing SH. The WLAM ensures better view of the soles thickness by trimming the toe, which could reduce the amount of too thin soles when claw trimming.

In the present study it could be hard to separate the method from another definitive factor such as the claw trimmers. One of the claw trimmers is a teacher at the claw trimmer course in Denmark and therefore she should be one of the best at this method. If the study had been performed with multiple claw trimmers, one would have to find out whether the claw trimmers would interact with the result of the method being preventive.

The present study was performed as a quasi-experimental study design, which has its limitations. The quasi-experimental study design is often used when it is not possible logistically or ethically to conduct a randomized controlled trial (Harris et al., 2006). Harris et al. (2006) estimated that the most substantial limitations of these studies were internal validity and lack of random assignment of the study groups. Harris et al. (2006) refer to a hierarchy where the highest step is the most reliable study design. At the top step there is an interrupted time-series study, where multiple measurements pre- and post-incidents are taken. In the present study, there are claw trimming registrations from the different herds at multiple times recorded throughout the 4 years, which would categorize this study as an interrupted time-series study. According to Harris et al., (2006) this type of study makes it easier to address and to control confounding elements. Since there have been no other known studies investigating the effect of WLAM, this study cannot be used to compare results to others. On the other hand, it can start a discussion about whether the claw trimming methods commonly used in Denmark and around the world are the most optimal.

In the analysis, calculations of interactions were performed, but due to convergence they were not successful and not included in the final study. The herds were the most interesting variable to investigate considering interactions with the results. This was checked by doing the cross-validation of the OR when removing one herd at a time. Since the herd cross-validation did not show any significant signs of any herds changing the OR significantly, the interaction calculation was deemed of no importance for the present study. Herd D was half the size of the other herds and therefore it could have impacted the analysis because a smaller herd can be managed differently than a larger herd. This could be visible in herd D since they had less than half of the prevalence of SU and WLA when claw trimming with the DAM. Nevertheless, the study found that herd D still had a significant reduction of SH, SU and WLS when cross-validating and claw trimming with the WLAM.

The data of the present study is quite unique, based on the known quality of the claw trimmers data. Furthermore, the herd selection criteria were based on the assumptions that it was the same cows, the same claws, the same management system and the same housing systems, within the different herds. There is less insecurity of what has been going on within these 4 herds than there would be with a larger population of different herds. The dataset is also unique since it has a known date where the trimming methods changed and the same people registering CHDL in the same way.

To further investigate whether the WLAM is a better claw trimming method, a randomized experimental study design should be performed. A randomized experimental trial where the cows would be randomly placed in one group being trimmed with the DAM and one group being trimmed with the WLAM. This would secure that the animals would be going through the same changes taking place in the different herds. To perform this study would be difficult, since two different methods of trimming within the same herd gives some logistical problems. Therefore, the present study with its unique dataset may produce a valuable contribution towards the study of effect of claw trimming methods on CHDL.

Experiment 2

Clinical observations can be prone to inaccuracy, both within and between observers. The authors ESC and NC tried to calibrate the scores and set certain markers to define the different scores in order to reduce this bias. Flooring, moisture and pain might lead to a more cow-hocked stance (Telezhenko & Bergsten, 2005). Therefore, the weather and flooring the heifers/cows were scored on should be the same. In this study the cows/heifers were in free stalls and there was therefore no control over the different flooring or moisture when retaking the RLRV scores.

Capion et al. (2008) assumed that cow-hocked cows bore more weight on the lateral claws. Nuss et al. (2020) contradicted this by measuring the pressure of the lateral and medial claw and concluded that the lateral claw bore the most weight, whether the cow had a parallel or cow-hocked hind leg conformation. Nuss et al. (2020) measured the weight distribution before and after claw trimming. However, they did not observe whether the RLRV score changed after claw trimming with the functional claw trimming method. It could be discussed whether functional trimming in Nuss et al. (2020)'s study had an effect on the RLRV score, since the functional claw trimming method mostly takes the length of the claw into consideration and takes no consideration to the individual cow's claw conformation. The present study indicates that the WLAM can improve the hind leg conformation by increasing the RLRV score.

Cow-hocked cows have more claw disorders compared to cows with a parallel stance (Capion et al., 2008). There is a genetic correlation between the RLRV score and the CHDL (Heringstad et al., 2018; Ødegård et al., 2014). The assumed extra weight on the lateral hind claw in a cow-hocked cow lead to the assumption of increased SH. This was contradicted by Nuss et al. (2020), whom did not find any significant difference in weight distribution of the lateral hind claw in cows with parallel or cow-hocked leg conformation. This indicated that we know that cow-hocked cows have an increased amount of CHDL, but the reasons why have not to my knowledge been found. However, the effect of claw trimming methods on the cow-hocked cows could be investigated to look into the different method's influence on the rear leg conformation and claw disorders. The present study finds an effect of claw trimming with WLAM on the RLRV score but does not investigate the effect of RLRV score on CHDL. On the other hand, Experiment 1 presents a difference between the prevalence of CHDL when trimming with the WLAM compared to the DAM. If the DAM does not change the RLRV score, the change of RLRV score when claw trimming with the WLAM could be speculated to reduce CHDL.

This study does not investigate whether the DAM corrects the RLRV score and cannot therefore conclude that the WLAM is better than the DAM in this circumstance. Capion et al. (2008) examined heifers five times from 41 d. before calving until dry off. One of the objectives of this study was to describe the dynamics and associations between abnormal hind leg conformation and claw lesions in heifers during their introduction to the dairy herd. The cows in Capion et al. (2008)'s study were claw trimmed with the DAM and they found that the RLRV score decreased during lactation. This meant that the cows during the lactation had an increased cow-hocked stance. It could be speculated that the present study and Capion et al. (2008)'s study could potentially indicate that the RLRV score improves when using the WLAM compared to the DAM. The pros of comparing the two studies are relative similar sample sizes both of cows and different herds. The claw trimming methods of both studies are known and can be compared since both studies include claw trimming with the DAM. The cons are that the present study does not compare the effect over time, which Capion et al. (2008)'s study does. To further investigate whether there is an association between RLRV and trimming method, a randomized experimental study with a larger test population and claw trimming with both the DAM and the WLAM could be performed to analyze the difference between the correction of the

RLRV. An investigation of the effect of increasing the RLRV score on the claw health could be performed by scoring RLRV scores before and after claw trimming over a period and registering the CHDL of the different cows.

CONCLUSION

The results from Experiment 1 in this study demonstrates that there is a difference between the CHDL prevalence when trimming with the WLAM compared to the DAM. The WLAM had significantly lower prevalence of SH, SU and WLS compared to the DAM. The WLAM focuses on individual claws and therefor allows for correction of the individual cow's problems. This could help the cows towards a more parallel conformation of the third phalanx and the claw capsule. Further studies with control groups and a randomized experimental trial are required to establish a possible causal relation between trimming method and incidence of CHDL. The purpose of claw trimming is to decrease and prevent claw disorders. These further studies could investigate whether the trimming methods have the effects on claw health one would expect. Potentially, further studies could investigate the different methods of claw trimming to increase the use of the one method fulfilling the purpose of claw trimming the most.

The results from Experiment 2 in this study indicates that the WLAM can increase the RLRV score and thereby change the rear leg conformation to a less cow-hocked stance. Disagreement in earlier literature regarding whether the cow-hocked cows have more weight on the lateral claw compared to the parallel cows, has led to the need of further research on the effect of the hind leg conformation. Further research should focus on the methods and the scoring of RLRV before and after trimming, to study the effect of claw trimming method on the RLRV conformation. In addition, further studies could include the use of a pressure plate to register weight distribution before and after trimming and combine it with the claw registrations and methods of claw trimming. This could be done to investigate whether an increase in the RLRV score after claw trimming benefits the claw health.

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