Effects of trimming on dairy cattle hoof weight bearing surfaces and pressure distributions

Victor CARVALHO[1]
Irenilza Alencar NÄÄS[1]
Ray Allen BUCKLIN[2]
Jan Keith SHEARER[4]
Leslie SHEARER[3]
Valmir MASSAFERA JR.[1]
Silvia Regina Lucas de SOUZA[1]

1 - Colégio de Agricultura da Universidade de Campinas, Campinas – SP
2 - Agricultural and Biological Engineering of University of Florida, Florida - EUA
3 - Veterinary Medicine College, Large Animal Clinical Sciences of University of Florida, Florida - EUA

Correspondence to:
VICTOR CARVALHO
Colégio de Engenharia Agrícola
Universidade Estadual de Campinas
Cidade Universitária Zeferino Vaz, s/n
13083-970 – Campinas – SP
victor.ciaco@terra.com.br

Received: 08/09/2004
Accepted: 13/07/2005

Abstract

Claw lameness can be associated to biomechanical factors caused by unbalanced pressure distribution under the hooves when cows are confined in modern dairy operations with hard concrete flooring. In the present study, an original claw subdivision[4] was slightly modified to differentiate between the anterior (typical sole lesion spot) and posterior portions of the medial sole, and to emphasize the maximum pressures applied only on the area of contact without including the total area within these regions during midstance. The results, obtained showed significance ($p < 0.044$) for the interaction among Group, Leg and region (G*L*R). It was observed that the rear portion of the claws (heels) on the hind limb of untrimmed cows, are more stressed than the heel region on trimmed cows (23 % *versus* 16.72% of total pressure applied on the claw for untrimmed and trimmed respectively). The typical sole lesion spot pressures were increased slightly on trimmed cows as compared to untrimmed (20.20% *versus* 15.9%). The front feet presented differences in pressure concentration on the lateral sole between both groups (29% *versus* 23.25% for untrimmed *versus* trimmed respectively). It was concluded that, although the differences were small (5%) changes in pressure concentration, untrimmed cows stress more the sole lateral as compared to trimmed on the front feet, and on the rear feet, they stress more the heel region whereas trimmed cows tend to have a slight better balance among regions. Conversely, when cows are trimmed, the typical sole lesion spot concentrates more pressure than the heel itself (20.20% *versus* 16.72% respectively) and may favor the occurrence of sole ulcers.

Key-words:
Pressure distribution.
Claw.
Sole ulcer.
Lameness.

Introduction

Lameness is among the most prevalent and costly of clinical disease conditions in dairy cattle. Causes include rations and/or feeding conditions that encourage rumen acidosis; confinement of cows to harder, wetter, more abrasive floors; or un-grooved floors that are smooth (and thus slippery, etc.). Flooring is of particular importance, because of pressure distribution and redistribution on claws. Uneven weight-bearing of hoof walls of cows managed on hard floors (i.e. concrete) lead to pressure redistribution on claws and thus causes greater pressure concentration and stress on claws[1]. The typical sole lesion spot is considered to be the region where the highest pressures concentrate under the foot and occurs usually associated under conditions of confinement on concrete and poor trimming practices and is the site on the lateral claws of the rear foot where sole ulcers eventually develop[2,1].

Specific information concerning the incidence of foot diseases in cattle in Brazil as well as in the United States is limited. However, the American incidence is believed to be similar to that reported in the United Kingdom where surveys involving 1821 herds reported that the average incidence of lameness requiring treatment by a veterinarian was 5.8% of cows. Of these 5.8%, 88% involved the foot and most of foot lesions involved the rear feet, with 85% of lesions occurring in the outer claw. Studies at University of Florida Dairy Research Herd in 1995 reported 178 clinical lameness events of 346 (51 cases/100 cows) affecting 120 (35%) cows; 27/120 had more than one clinical event[2]. The economic loss incurred as a result of disease (i.e., sole ulcers) arises primarily from the consequences of the disease and not the cost of treatment. Walking impairment imposed by hoof lesions causes decreases in feed and water intake, resulting in marked losses in body weight and milk production; and also poor reproductive performance[3]. British researchers estimated the cost of lesions such as sole ulcers, white line disease and digital dermatitis to be approximately $627/case, $257/case and $128/case, respectively. Data from University of Florida using a herd of 346 cows computed losses of $58,266.00 due to clinical lameness during one-year study using the same figures[2]. Lower milk yields, reduced reproductive performance, higher involuntary culling rates, discarded milk, among others, accounted for the majority of economic losses.

The objective of this study was to assess the typical sole lesion spot weight-bearing as compared to the pressure distributions of the other regions under the hooves of dairy cows for two groups : Untrimmed (unbalanced) and trimmed (balanced) and associate these changes in pressure distribution to the lameness etiologies of biomechanical origin.

Material and Methods

The experiment consisted of 31 Holsteins cows divided into two groups: A – Balanced/Trimmed claws (Control) with 14 cows, and B – Unbalanced claws with 17 cows, from the Dairy Research Unit non-lactating herd at the University of Florida,Gainesville, FL, USA. Data were collected during one month from June 5th to July 3rd of 2003. Un-trimmed group (17 cows) data collection started on 5th of June 2003 and lasted until the 26th of June 2003. The 14 cows belonging to the trimmed group were trimmed before starting the experiment, every other day, from 26 of June 2003 to 03 of July 2003. From trimming the cows, it was observed that their hooves were about 6mm overgrown in height at the heel and about 12.7mm to 19mm overgrown in length at the toe. Data on degree of claw overgrowth, of the un-trimmed group was not assessed. The average weight of the cows accounting for both groups was 644 kg. None of the cows presented signs of clinical lameness during the study.

The MatScan® (Tekscan Inc.) was mounted on top of a force platform specifically designed for it, and therefore having the same dimensions . The force platform was built in order to measure the correct force under any given individual limb and use it to correctly calibrate the MatScan sensor (correct calibration according to the manufacturer).

The force platform consisted of a metal plate base with four 113 kg load cells in each corner and a top metal plate supported only by the load cells that read the load. The top plate was first secured to the load cells with screws and free from any other contact through a design that resembles a ball and socket joint. Next step was the calibration of the force plate for converting the voltage readings of the load cells into weight. The procedure was done using several known metal weights of approximately 24 kg each. A data logger was programmed for reading the voltage outputs and converting them into force values.

The calibration of the force plate had readings matching the known loads measured with an industrial weight scale of 2,268 kg maximum loads. The calibration data was plotted and a regression fit, which gave a high correlation coefficient (R^2 = 0.9998).

To analyze the pressure distribution on claws during the stance phase of a cow's walking stride, a wooden platform was built to house the force plate and Matscan system. The wooden platform was designed with dimensions of 680 cm x 91 cm x 8.9 cm to fit inside a restraint corridor. (Figure 1).

The length of the platform was chosen according to the length of an average large Holstein cow (approximately 2.17m) and to assure at least two complete strides before stepping onto the force/pressure system. As the cows stepped onto the platform system, three positions were selected for the analysis: a- deceleration; b- midstance and c-acceleration, based on the force readings and positions of the leg. In order to analyze the pressure under the regions of each claw, an Excel spreadsheet was designed and programmed with a coordinate system and predefined formulas for calculating the forces and pressures of the four proposed regions: heel (4), lateral sole (1), medial sole (2) and toe (3) (Figure 2A). A new subdivision was adopted in order to emphasize the typical sole lesion spot and to account only for the contacted surface pressure distribution rather than account for the total area that comprised the regions, loaded or not, presented in the previous work[4], which may have diluted important areas of pressure concentration. The new procedure removed the zeros (from the sensor output) which were being accounted (increasing the area and reducing the pressure for all regions) to form the complete contact surface under the foot but were not loaded at all. The new subdivision, subdivided the medial sole (Figure 2B) for both: lateral and medial claws, into anterior medial sole-typical sole lesion spot[1] and posterior medial sole-near the toe on the lateral and medial claws.

The SASÒ V.8.2 was used for the statistical analysis, and the statistical design was carried out using PROC MIXED at a default 95% confidence interval. The statistical design consisted of two groups: A – Balanced claws (control) and B – Unbalanced claws. The arrangement used was 2 x 4 x 2 x 5. This represents two groups of cows: 14 cows in group A and 17 cows in group B totaling 32 cows, 4 or less legs per cow (an average 2 legs per cow, one front and one rear), 2 claws per leg and 5 regions per claw yields 630 observations. The procedure tested the main fixed effects: Group (G), Leg (L), Claw (C) and Region (R) and their 2-way, 3-way and 4-way interactions. The results presented below were obtained with analysis of the normalized data.

Normalizing pressures to the total pressure, in this procedure, expresses pressures as a percentage (%) of the total pressure applied under the claw by dividing the pressure at a given region by the total pressure applied on that claw. This procedure was performed in order to accommodate the results to the differences in cow different weights and therefore the maximum pressures applied and under different velocities. Cows walking faster have greater force components and not necessarily an increase in surface area resulting in greater pressures and differences due to this may influence some interpretation of the results.

Results and Discussion

At midstance, the highest order significant interaction for this analysis, at a 95% confidence interval, was G*L*R (group*leg*region) with $p < 0.0044$. The G*L*R interaction LSMeans for the right front and rear feet are shown in Figures 5 and 6. Front feet showed an overall better equivalence among the normalized pressures under the five regions of interest within cows of same groups. The highest pressures were located at region 1 (weight bearing border portion of the sole) with pressures of 28.99% and 23.25% of the total pressure applied on the claws for untrimmed and trimmed respectively. The second highest pressures on the front feet were balanced having values on the range of 19% to 22% of total for regions 5 (heel), 4 (toe) and 2 (posterior portion of medial sole) and the lowest pressures occurred at region 3 (anterior portion of the medial sole). Between groups, region 1(lateral sole and weight bearing border) of untrimmed cows presented a slight higher pressure concentration then trimmed cows. The mean (%) difference between them was about 5% of the total pressure applied on the claws and accounted for 28.98% vs. 23.25% for untrimmed vs. trimmed respectively, (Figure 3). Region 3, posterior portion of the medial sole, also changed slightly between groups (4%), and was higher on trimmed cows (13.67%) as compared to untrimmed (9.7%). This increase seemed to come exclusively from the weight bearing border region (1) implying a small regain of balance among regions on the front feet accounting for lateral and medial claws. The pressure redistribution on the rear feet also accounted for the same amount of changes (5-6%) overall (Figure 4).

The highest pressures on the rear feet of both trimmed and untrimmed cows also occurred on region 1 with 30.97% for untrimmed vs. 29.10% for trimmed but were not different between groups, followed by regions 4, 5 and 2 which had the same pattern as front feet. The main differences on the rear feet caused by trimming, although small, occurred on regions 5 and 3 and to a lesser extend on region 2.

These changes accounted for a small improvement towards the anterior part of the claw, that is, the higher pressure concentrations at the heel (region 5) decreased from 22.99% to 16.72% (~6% difference, $p < 0.05$) increasing mostly at the anterior portion of the sole on trimmed claws from 7.09% to 12.8% (~ 6% difference, $p < 0.05$), for untrimmed vs. trimmed respectively.

L*C*R (Leg * Claw * Region) interaction was statistically significant (p <

Figure 1 - Wooden platform inside restrain corridor

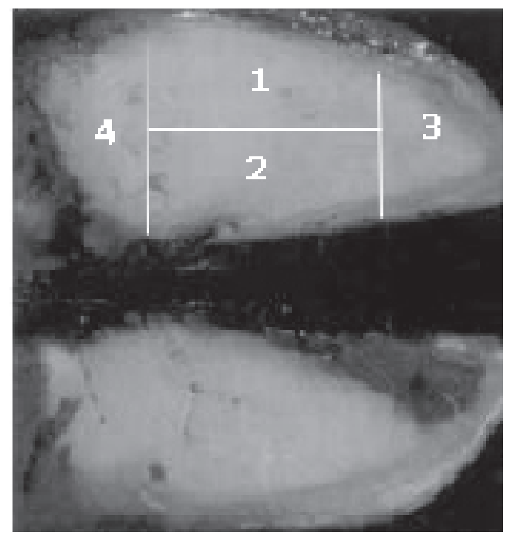

Figure 2 - Old claw subdivision (A)

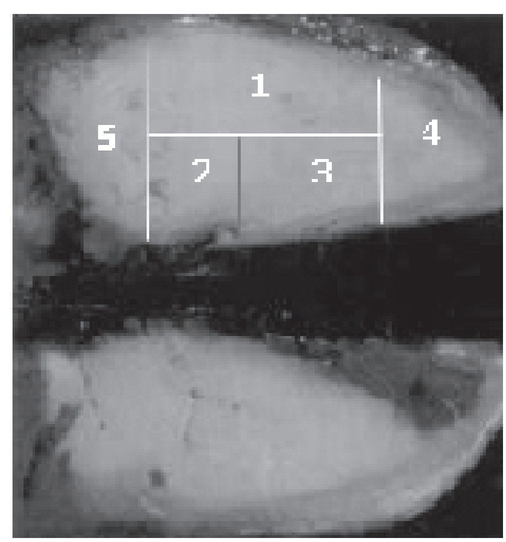

Figure 2 - New claw subdivision (B)

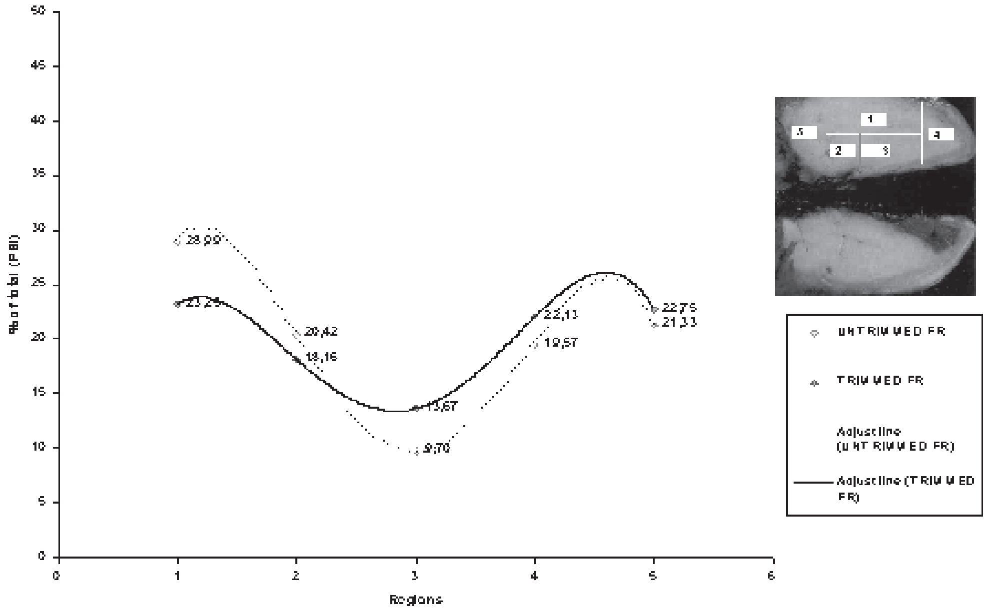

Figure 3 - Front right feet LSMeans for G*L*R interaction

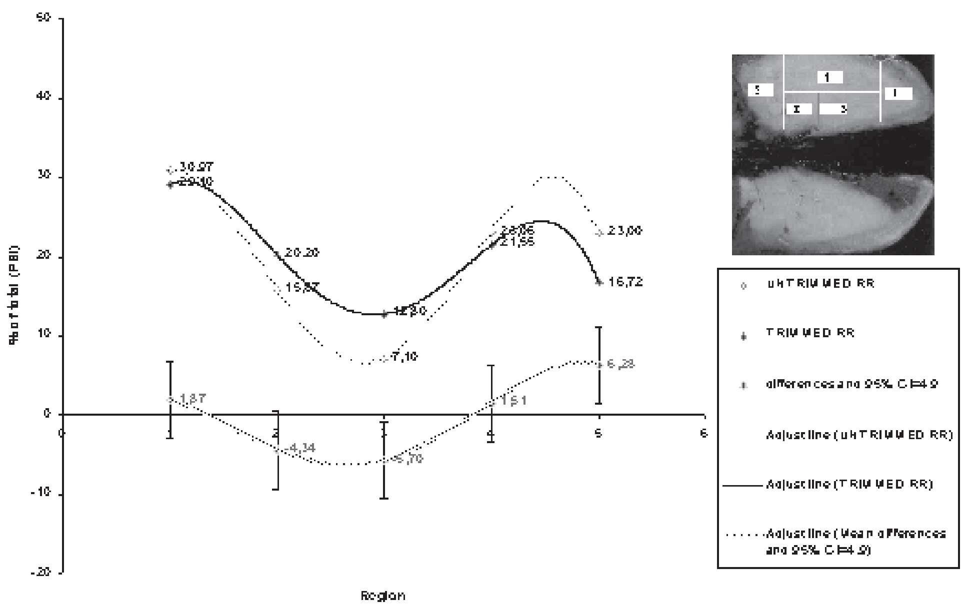

Figure 4 - Rear right feet LSMeans for G*L*R interaction, mean differences and their 95% CI. (Intervals including zero are not statistically significant á = 0.05)

0.0001) and its graph was plotted in order to evaluate the changes seen between groups at a claw level. From figure 5, it can be observed that the region 5 which was statistically different between groups (Figure 4) was also statistically different between claws. The outer claw is the claw that holds the major pressures at the heel (23.08% *versus* 16.63% for outer versus inner respectively) with a 6.44% difference. Hence, un-trimmed cows, has approximately 6% more pressure concentration at the heel of the outer claws as compared to trimmed. The same trends can be observed for regions 1, 2 and 4 where sole lateral's major weight bearing is on the inner claw, the typical sole lesion spot (2) is more stressed at the outer claws and toe region is more stressed at inner claws.

The latter regions differences were not statistically significant between groups. Region 3, sole medial, was not statistically different between claws but were statistically different between groups (Figure 4).

This increases could be labeled as an improvement because, great pressure concentrations on the rear portions of the claw (heel and anterior portion of medial sole) is thought to favor the incidence of haemorrages and lesions at that point and on un-trimmed cows they are shown to be somewhat greater and also in the outer claw[1]. According to figure 4, trimming may cause a relief of those portions by redistributing this pressure to the anterior portion of the sole. Conversely, the typical sole region spot is also increased with trimming from 15.86% to 20.20%, not statistically significant between groups but significantly ($P < 0.05$) larger at the outer claw. This particular region (typical sole lesion spot, Raven[1] seemed to be more prone to localized pressure concentration when cows were trimmed not appearing to be obviously overloaded in un-trimmed claws as expected. It is important to remember that these are small changes (~6% of total pressure redistributions) but occurred with a relative median degree (12.3mm to 19mm) of excessive horn which gives claws approximately 90mm to 95mm long. This scenario, although speculative, could become concerning in a long run at extreme degrees (not experimented) of overgrowth such as claws ~ 135mm long, a 60mm excessive horn formation[5], where pressures concentration increases at rear portion of claws (heels), if proportional to changes experienced here, could increase from 6% to 18%. It is controversial the question whether removing higher pressure concentrations from the heel but relocating it to the soft sole, even if implying in a small rebalance of the claw as a hole, is beneficial

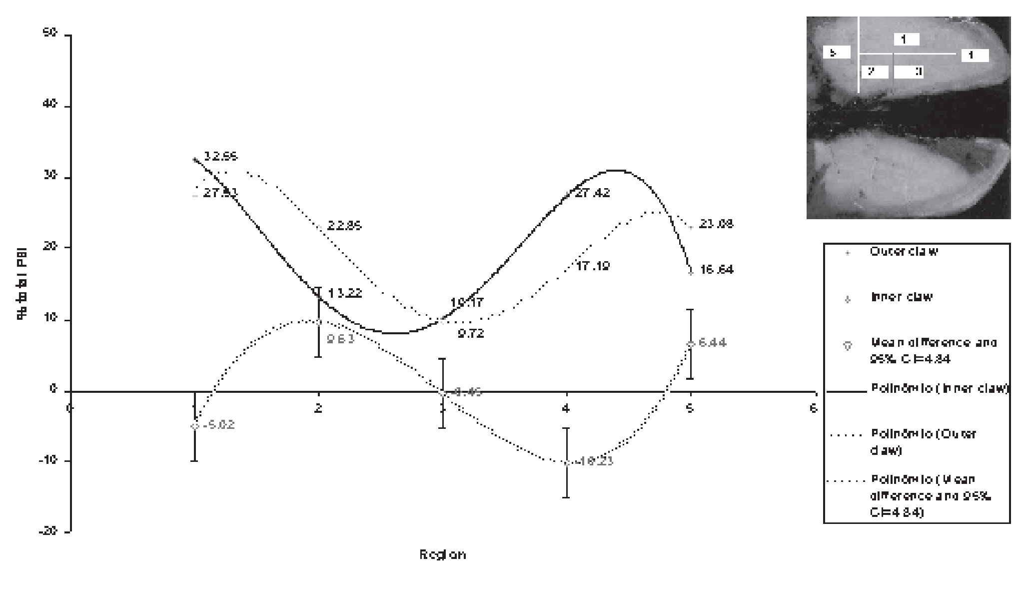

Figure 5 - Rear right feet LSMeans for L*C*R interaction, mean differences and their 95% CI. (Intervals including zero are not statistically significant á = 0.05)

or damaging as far as the development of sole ulcers and lameness.

Conclusions

According to the data obtained in this study, claw trimming may provide some balance to the pressures applied to various regions of the claws of the front and hind feet by redistributing some of these pressures to the medial sole area. However, it is questionable whether shifting pressures from weight-bearing border (lateral sole) towards the softer portion of the sole in order to achieve balance is the correct approach. Lameness of biomechanical origin is thought to be related to the overburdening of soft tissues in the axial region of the claw anterior to the heel bulb caused by claw overgrowth under confinement housing conditions. The heel bulb and lateral sole were the major weight bearing portions on the rear feet of untrimmed claws as compared to trimmed which appeared to localize pressure concentrations on regions 1 followed by 2 and 4. The results of pressure distribution between these two groups lead to the assumption that there a tendency of overburdened soft sole at the vulnerable spot region caused by trimming.

New experiments assessing weight bearing and pressure distributions on lower and higher degrees of claw overgrowth contrasting the tendencies found in this experiment would help to elucidate the question whether the pressures increases are proportional to the length of the claw and if this may be causing mechanical overburdening of the heel and sole predisposing or aggravating the process of lameness on the rear feet of dairy cows confined on hard floors.

Efeito do casqueamento na distribuição de pressões e suporte de peso na superfície dos cascos de vacas leiteiras

Resumo

Laminite (manqueira) pode ser associado a fatores mecânicos, causados por falta de balanceamento na distribuição de pressão na sola dos cascos de vacas confinadas em instalações modernas, que utilizam pisos de concreto. No presente estudo, a subdivisão original dos cascos de vacas leiteiras foi modificada para diferenciar-se entre a porção anterior (local típico de lesão) e posterior da sola medial dos cascos, e para enfatizar as pressões máximas aplicadas somente na área de contato não levando em consideração a área total da sola. Os resultados mostraram significância estatística ($p < 0.044$) para a interação entre Grupo, Pata e Região (G*L*R). Foi observado que a porção posterior (calcanhar) das patas traseiras de vacas não-casqueadas foram estressadas mais intensamente que de vacas casqueadas (23 % *versus* 16.72% da pressão total aplicada nas patas em não-casqueadas e casqueadas respectivamente). As pressões na região do local típico de lesão aumentaram em animais casqueados comparado com não-casqueados (20.20% *versus* 15.9%). As patas da frente apresentaram diferenças na concentração de pressão da sola lateral (29% *versus* 23.25% em não-casqueadas *versus* casqueadas, respectivamente). Foi concluído que, apesar das diferenças serem pequenas (5%) mudanças nas concentrações de pressão, vacas não-casqueadas estressaram mais a porção da sola lateral, comparado a vacas casqueadas nas patas da frente, enquanto nas traseiras elas estressam mais a região do calcanhar, e as vacas casqueadas tendem a ter uma distribuição melhor de pressão entre as regiões. No entanto, quando as vacas são casqueads, a região típica de

Palavras-chave:
Distribuição de pressão.
Patas.
Úlcera de sola.
Manqueira.

lesão tende a concentrar mais pressão do que o próprio calcanhar (20.20% *versus* 16.72% respectivamente) podendo favorecer a incidência de úlcera de sola.

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