Behaviour and claw health in tied dairy cows with varying access to exercise in an outdoor paddock

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Abstract

The aim of this study was to compare the effect of different access to an exercise area on behaviour, time to lie down, claw conformation, claw lesions and milk production. The study was carried out on an organic dairy farm with 52 tied cows. The cows were randomly assigned to one of four treatments, with 13 cows in each group, and matched according to lactation number, milk production and whether or not they were de-horned. The treatments were: exercise every day (E7), exercise two days per week (E2), exercise one day per week (E1) or no exercise (NoE). Exercised cows were brought to one of two outdoor paddocks for 1 h. Observations of behaviour were made using one-zero sampling during the 1 h exercise, twice per month and treatment, during the six months of winter housing (780 min per group in total). Treatment NoE was observed in their stalls during the same time as the other treatments were exercised. The duration of the two phases of the lying down movement was recorded four times per cow. Claw traits were recorded at trimming at the beginning and the end of the six month study period. The farm measured the individual milk yield one day per month.

There was an increase in the mean percentage of walking and trotting with decreasing access to exercise. Cows in the E1 and E2 treatment explored the environment more than cows in the E7 treatment. The wear of the claws during the winter was greater for the exercised cows compared to NoE and resulted in shorter claws at spring trimming. There was no difference in the duration of lying down movements for different treatments, nor a difference in milk production.

These results show that adult dairy cows used the time to walk, trot and explore the environment when given access to an outdoor paddock, and that exercise had a positive effect on the claw conformation.

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Keywords: Dairy cows; Exercise; Behaviour; Lying down; Claw lesions; Claw conformation
1. Introduction

The tradition of tying up dairy cows in Sweden goes back to the early middle ages (Myrdal, 1999). Presently, 75% of all Swedish dairy herds are tied up continuously during the housing season but the Swedish animal welfare legislation requires that they are out on pasture for two (north of Sweden) to four (south of Sweden) months during the summer. The tie stall restricts the cow’s possibility to walk, to have normal social contact with cows other than her neighbours and to choose her lying place. On the other hand, tied animals get individual care and feeding, and they are less challenged socially by other animals. New legislation for organic production within EU only allows housing of cows in tie stalls if they are regularly exercised (EC directive, 1999). However, cows may not have a motivation to move per se, and may only move when motivated to get access to food, resting place or social contact (Zeeb, 1983; Gustafson, 1994). On the contrary, calves and heifers seem to build up a motivation to move with time of confinement (Jensen, 1999, 2001). In calves the motivation to perform locomotor play behaviour increased significantly with days of confinement (Dellmeier et al., 1990; Jensen, 2001) and in heifers galloping and bucking increased after one week of confinement (Jensen, 1999). Dellmeier et al. (1985) showed that calves tied in stalls or in individual pens performed more bucking, cantering and trotting and had more social encounters when tested in an open-field test than calves kept in hutches or in yards. The studies on adult cattle have mainly focused on daily exercise versus no exercise (Krohn et al., 1992; Krohn and Munksgaard, 1993; Krohn, 1994; Gustafson, 1994). In the study of Gustafson (1994) the cows were moved 1 km away from the barn from where they walked back on their own. In a 2.5-year long study Krohn and colleagues (1992) showed that cows that could move freely between deep litter indoors, a yard outdoors and a pasture walked outdoors every day. The tied control group that was exercised once a day walked 0.22 km per day. These findings imply that cows walk even if it is not necessary for them to do so to get access to food, water, etc. To investigate how quickly the motivation for movement increases in cows, different lengths of confinement have to be tested.

The cows lying down behaviour has been used before to investigate the effect of exercise on the time it takes to perform the lying down movement (Gustafson, 1994; Herlin, 1994). In those studies the lying down movement was divided into two phases. The first phase starts with the cow showing pendulum movements of the head and sniffing the ground, and ends when the first carpal joint reaches the ground. At that moment the second phase starts and it ends when the cow is lying down. Gustafson and Lund-Magnussen (1995) showed in a four year study that permanently tied cows had a significantly longer first phase than did cows exercised every day.

In a confined management system the biology and behaviour of the animal are often ignored and can result in severe animal welfare problems (Baxter, 1983). Lameness is the third major production disease complex of dairy cows after mastitis and infertility, due to the high incidence and the high cost of each individual case. More than 90% of the lameness cases are related to claw disease (Murray and Downham, 1996), and in order to better understand these, both claw lesions and claw conformation should be studied. Abnormal claw shape, improper claw size and poor horn quality have all been shown to predispose to or be a result of claw lesions (Russell et al., 1982; Distl et al., 1990).
The most widespread lesions, contributing to poor claw health and lameness in dairy cattle under Swedish conditions, are sole haemorrhages, sole ulcers, interdigital dermatitis and heel horn erosion (Andersson and Lundström, 1981; Manske et al., 2002). The environment and management play essential roles in their prevalence and severity. In intensive dairy systems, and especially in tie stalls, the cows have little opportunity to exercise. Exercise gives stronger muscles and joints and reduces the prevalence of hock injuries (Gustafson, 1993). Moreover, active locomotion gives the cows optimal blood circulation in the legs and so helps supply nutrients and oxygen to the keratin-producing horn tissues. In laminitis the local blood circulation decreases (Ossent et al., 1997). However, when the walking surface was too hard, loose housed cows developed more lameness and especially lesions associated to laminitis (Bergsten and Herlin, 1996). In tie stalls, lameness and claw disorders increased with increased exercise (Krohn and Rasmussen, 1992).

The aim of this study was to compare the effect of different access to exercise on movements, exploration, grooming, ruminating and social interactions. We also wanted to study the effect of different access to exercise with no access to exercise on time taken to lie down, claw lesions, claw conformation and milk production.

2. Material and methods

2.1. Housing and animals

The study was conducted on an organic dairy farm in the south west of Sweden during the housing season from November 2000 until May 2001. The 52 dairy cows of the Swedish Red and White breed were kept in tie stalls with cross binding, where each stall measured 1.20 m × 1.75 m and had adjustable feed gates. The floor was equipped with rubber mats and chopped straw was used for bedding. The stalls were placed in two rows each with 26 cows, facing a common feeding manger. The cows were fed a total mixed ration four times a day and were milked twice a day in the stall. Every cow had ad libitum access to water in individual water bowls. When exercised, the cows were released into one of two outdoor paddocks of approximately the same size (3220 and 3040 m²). The floor in the barn was concrete and the ground in the passage way out to the paddocks was made of concrete for the first 3 m followed by gravel. The ground in the paddocks initially consisted of clay soil covered with grass. However, during the rainy autumn parts of the grass disappeared and the surface became muddy. In January and February the ground was frozen and temporarily some snow covered the ground. From March the ground was muddy again and in April it started to dry up. In the larger paddock there was an empty feed trough with a small roof and an empty water container. There was no water or feed in any of the paddocks. Several of the cows suffered from mange around the tail base during the winter, but they were not treated for this.

2.2. Experimental design

All the 52 cows on the farm were matched in groups of four according to lactation number, milk production and whether or not they were de-horned. The four matched cows
were randomly assigned to one of four groups, resulting in 13 cows per group at the start of the study. The four groups were randomly assigned to one of the following treatments:

1. Exercise 1 h per day, 7 days a week (E7).
2. Exercise 1 h per day, 2 days a week, Mondays and Thursdays (E2).
3. Exercise 1 h per day, 1 day a week, Wednesdays (E1).
4. No exercise during the period (NoE).

Exercised cows were individually released from their cross binding and allowed to walk out to one of the two paddocks where they were exercised between 13:00 and 14:00 h. The group exercised daily (E7) was released into one of the two paddocks according to a random schedule. The other two groups, E2 or E1, were released into the other paddock. The groups were never mixed in the same paddock nor in the passage way. Cows belonging to the same treatment were tied in the same area of the barn, but cows could change place within that area after exercise. About 1 h before the observations, the cows were painted (water-based white colour) with a number on both sides of the body and near the tail base to facilitate individual identification. Cows that were culled during the study were not replaced. Some of the cows did not lactate during the whole study period.

2.3. Behavioural recordings

Observations of behaviour were made on all cows in the groups during a period of 65 min, once per week, two weeks per month for six months of the housing season. In total this gave 12 times 65 min (780 min) observation time per treatment. The recordings were made during the same time period, i.e. 13:00–14:00 h, in the paddocks for the exercised groups and in the stable for the non exercised group. The behaviours were recorded on a portable tape recorder with one-zero sampling. The behaviour of each cow was recorded for 30 s per cow, in a random order, and repeated nine times, thus resulting in 10 times 30 s recording time per cow and week. The behaviours recorded are listed in Table 1.

In February and March, five months after the cows were tied up for the winter housing, we recorded the time taken to lie down for the cows in all four treatments. Two recordings per cow and month were made by direct observations. The time was measured from the moment when the cow started to move her head in a pendulum movement close to the ground until the first carpal joint reached the ground (phase 1), and from this position until she was lying (phase 2). One day per month the milk yield was individually measured by the farm manager according to the official milk-recording scheme (Swedish Dairy Association, Eskilstuna).

2.4. Claw recordings

Claw measurements, presence and severity of foot lesions as well as dirtiness of feet were recorded during claw trimming at the beginning and end of the winter housing (November 2000 and May 2001) according to procedures described by Bergsten (1995). Measurements of the left lateral hind claw were made before and after trimming. The length of the toe was measured with a vernier calliper of the dorsal border from the tip of the toe to the proximal end of the claw capsule at the coronary band. The diagonal was measured from the tip of
### Table 1
Behaviours recorded during observation of exercised and non-exercised cows

<table>
<thead>
<tr>
<th>Behaviour group</th>
<th>Behaviour</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk/trot</td>
<td>Walk</td>
<td>A four beat gait. Two or three hoofs touch the ground at any time depending on the speed&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Trot</td>
<td>A two beat gait. Two hoofs touch the ground at the same time, left hind with right fore and right hind with left fore&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Play</td>
<td>Gallop</td>
<td>Fast four-beat gait. All four hoofs touch the ground one after another followed by a phase of suspension in the air&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>Cow makes a jump from standing still with front legs or all four legs.</td>
</tr>
<tr>
<td></td>
<td>Buck</td>
<td>Cow kicking backwards with her hind legs in connection with gallop.</td>
</tr>
<tr>
<td>Explore</td>
<td>Sniff ground</td>
<td>Sniffing the ground in the paddock or in the barn.</td>
</tr>
<tr>
<td></td>
<td>Sniff object</td>
<td>Sniffing an object in the paddock or in the barn.</td>
</tr>
<tr>
<td></td>
<td>Lick ground</td>
<td>Licking the ground in the paddock or in the barn.</td>
</tr>
<tr>
<td></td>
<td>Lick object</td>
<td>Licking an object in the paddock or in the barn.</td>
</tr>
<tr>
<td>Self-groom</td>
<td>Lick self</td>
<td>Lick herself on any body part. Recorded which body part.</td>
</tr>
<tr>
<td></td>
<td>Rub interior</td>
<td>Rub body part against an object in the paddock or barn.</td>
</tr>
<tr>
<td></td>
<td>Rub self</td>
<td>Rub two body parts against each other.</td>
</tr>
<tr>
<td></td>
<td>Rub ground</td>
<td>Rub body part against the ground.</td>
</tr>
<tr>
<td>Ruminate</td>
<td>Lie ruminating</td>
<td>Lie down and ruminate the boluses of feed.</td>
</tr>
<tr>
<td></td>
<td>Stand ruminating</td>
<td>Stand still and ruminate the boluses of feed.</td>
</tr>
<tr>
<td>Eat</td>
<td>Eat</td>
<td>Eat food in the stall or grass in the paddock.</td>
</tr>
<tr>
<td></td>
<td>Sniff food</td>
<td>Sniff food in the barn.</td>
</tr>
<tr>
<td></td>
<td>Move food</td>
<td>Move food with the head in the barn.</td>
</tr>
<tr>
<td>Social</td>
<td>Sniff cow</td>
<td>Sniff other cow with the nose in contact or within 20 cm from the other cow.</td>
</tr>
<tr>
<td></td>
<td>Lick cow</td>
<td>Lick other cow on any body part.</td>
</tr>
<tr>
<td>Aggression</td>
<td>Threat</td>
<td>Lower the head towards other cow, who respond by moving in the opposite direction.</td>
</tr>
<tr>
<td></td>
<td>Push</td>
<td>Push other cow with the forehead against any body part.</td>
</tr>
<tr>
<td>Stand</td>
<td>Stand</td>
<td>Stand still without showing other behaviour.</td>
</tr>
<tr>
<td>Move</td>
<td>Move</td>
<td>Move one step forward, backward of sideways.</td>
</tr>
<tr>
<td>Lie</td>
<td>Lie</td>
<td>Lie down without showing other behaviour.</td>
</tr>
<tr>
<td>Other</td>
<td>Other behaviour</td>
<td>All other behaviours not included in the above list.</td>
</tr>
</tbody>
</table>

<sup>a</sup> Modified from Hurnik et al., (1985).

the toe to the proximal end of the heel (bulb). The toe angle was measured with an angel meter at 3 cm from the proximal edge of the toe wall.

### 2.5. Statistical analysis

Statistics on the behaviour, time taken to lie down and milk production were made in SAS version 8 for Windows. The lactation stages were grouped; (1) first to third month, (2) fourth to eleventh month, (3) dry cows and (4) heifers. The lactation numbers were merged into three groups; (1) heifers (before first calving) and first calvers, (2) second and third calvers and (3) fourth and fifth calvers. The behaviours of exercised cows were grouped (Table 1)
and for normally distributed behaviour groups analysis was by analysis of variance (Mixed effect model) including treatment (E7, E2, E1), month (November–April), paddock (left or right), lactation stage (1, 2, 3, 4) and lactation number (1, 2, 3) as fixed effects, and cow as a repeated and random effect. For the behaviour groups ‘explore’, ‘eat’ and ‘self-groom’ the model also included an interaction between treatment and month. Tukey–Kramer was used as a post-hoc test. The behaviour groups ‘social’ and ‘aggression’ were analysed with a Kruskal–Wallis test (SAS) to test for effect of treatment and with a Friedman two-way analysis of variance by ranks to test for effect of month. The behaviour group ‘play’ was transformed into a binary variable and analysed with a Chi-Square test for $k$ independent samples (Siegel and Castellan, 1988). The NoE cows were used when comparing the time taken to lie down, the milk production and the claw recordings with exercised cows. Time taken to lie down was analysed with Kruskal–Wallis test on the effect of treatment and age. The same test was used to test the effect of treatment on milk production.

Statistical calculations of claw measurements and claw diseases were made using Minitab (Release 12.21). The difference between claw measurements after autumn and before spring trimmings was considered as net growth, and is a balance between claw horn growth and wear. The claw measurements were analysed by analysis of variance (GLM-procedure) including lactation number (1, 2, 3, 4 and 5) and treatment (E7, E2, E1, NoE) as main effects. In the model for analysis of claw measurements before spring trimming the covariance on the measurement before autumn trimming was added. The multiple comparisons with control (NoE) were tested with Dunnett test. Lesion scores from four feet were summarized for each cow and then transformed into a binary variable, where cows with scores from two and higher were considered as affected, and cows with no lesions or maximum one slight injury on one foot as unaffected. Sole and white line haemorrhages and sole ulcers were combined into a complex; laminitis related lesions. The claw lesions were tested with the binary logistic regression including treatment as main effect and the following covariates: lactation number, month after calving, lesion score at the beginning of the experiment, and dirtiness of the claws. The logistic regression coefficients were converted into odds ratios (OR) of exercised groups to control. A 95% confidence interval (CI) was calculated for each odds ratio.

3. Results

3.1. Behaviour in the paddocks

3.1.1. Effect of treatment

There was an effect of treatment on the amount of ‘walk/trot’ ($P < 0.0001, F = 34.70$, d.f. = 2; Fig. 1). Cows performed more ‘walk/trot’ with decreased access to exercise. There was also an effect of treatment on the amount of exploratory behaviours recorded ($P < 0.0001, F = 17.29$, d.f. = 2). ‘Explore’ was observed more in the cows in treatments E2 and E1 than in the cows in treatment E7 (Fig. 1).

‘Self-groom’ was affected by treatment ($P < 0.01, F = 6.65$, d.f. = 2; Fig. 1). The cows that were only outdoors in the paddocks once a week (E1) performed more self grooming behaviours than the other cows (E2 and E7). In groups E2 and E1 the cows licked the rear
and middle part of the body more than the front part (E2: $\chi^2 = 7.54, P < 0.05$; E1: $\chi^2 = 14.0, P < 0.001$), but there were no differences for E7 in where they licked themselves. ‘Ruminate’ differed between different treatments ($P < 0.001, F = 35.54, \text{d.f.} = 2$). Of all the behaviours affected by treatment, rumination was performed most often by E7 and least often by E1 (Fig. 1). ‘Eat’ was significantly affected by treatment ($P < 0.001, F = 12.33, \text{d.f.} = 2$). It was observed more often in treatments E2 and E1 than in treatment E7 (Fig. 1). The only thing the cows in the paddocks could eat were dry grass during winter and short green grass during autumn and spring.

‘Play’ differed significantly between treatments ($P < 0.05, \chi^2 = 7.8, \text{d.f.} = 2$). In E7 ‘play’ was observed in 15% of the observations, in E2 17% and in E1 27.5% of the observations. We also found a difference between the treatments for ‘aggression’ ($P < 0.005, \chi^2 = 6.3, \text{d.f.} = 2$), where E1 had a mean score of 26.2 compared to E2 (mean score = 17.27) and E7 (mean score = 16.11). We found no effect of treatment for ‘social’ (n.s., $\chi^2 = 3.95, \text{d.f.} = 2$). It was also noted that only cows exercised every day were lying in the paddocks. When the temperature was above zero many cows in the group were observed lying in the paddock and one cow was even observed lying when the ground was covered with snow and the temperature was −14.5°C.

3.1.2. Effect of month

We found an effect of month on ‘walk/trot’ ($P < 0.0001, F = 8.28, \text{d.f.} = 5$). All groups walked and trotted more during November than during January ($P < 0.001$), March ($P < 0.001$) and April ($P < 0.001$) (Fig. 2). They also walked and trotted significantly more in December than in January ($P < 0.01$; Fig. 2). There was an effect of month on ‘self-groom’ ($P < 0.01, F = 3.00, \text{d.f.} = 5$). The cows groomed themselves more in March than in November ($P < 0.05$) and January ($P < 0.05$) (Fig. 2). ‘Ruminate’ was significantly affected by month ($P < 0.01, F = 4.84, \text{d.f.} = 5$). Cows ruminated more in December than in November ($P < 0.001$) and February ($P < 0.01$; Fig. 2). ‘Eat’ showed a totally opposite pattern in that the cows ate more in November than in December ($P < 0.01$) and January ($P < 0.001$)
Fig. 2. Behaviour groups affected by month (LSM ± S.E.) during totally 780 min of observation. Within each behaviour group tested for significant differences with Tukey–Kramer. These behaviours do not equal to 100%.

also more in February than in January ($P < 0.05$; Fig. 2). The amount of friendly social interactions did not differ over months (n.s., $\chi^2 = 3.94$, d.f. = 2).

3.1.3. Effect of interaction between treatment and month

We found an effect of the interaction between treatment and month on the behaviour groups ‘explore’ ($P < 0.01$, $F = 2.44$, d.f. = 10), ‘self-grooming’ ($P < 0.001$, $F = 5.70$, d.f. = 10) and ‘eat’ ($P < 0.001$, $F = 5.13$, d.f. = 10). The differences in explorative behaviours between treatments were not significant in November, February and April but cows in E1 had the highest value in all months except November when cows in E2 performed more explorative behaviours. It appears to have been the cows in E1 that contributed most to the overall increase in self grooming in March. E1 groomed themselves significantly more in February ($P < 0.01$, Tukey–Kramer), March ($P < 0.001$) and April ($P < 0.01$) than in November. Cows in E2 and E1 ate more than E7, but not in November and April.

3.1.4. Effect of paddock

The cows walked and trotted more ($P < 0.05$, $F = 4.74$, d.f. = 1) and ate more ($P < 0.01$, $F = 10.19$, d.f. = 1) in the left paddock than in the right paddock. A lot of the explorative behaviours recorded in the right paddock were cows sniffing and licking the empty feed trough.

3.1.5. Effect of lactation number and lactation stage

There was an effect of lactation number ($P < 0.001$, $F = 7.22$, d.f. = 2) on ‘explore’. Heifers and first calvers explored the paddocks more than second to fifth calvers (Fig. 3). There was also an effect of lactation number on ‘self-groom’ ($P < 0.01$, $F = 6.22$, d.f. = 2). Second to fifth calvers groomed themselves more than heifers and first calvers (Fig. 3). Heifers and first calvers ate more than second to fifth calvers (Fig. 3).

Lactating cows explored the environment more than dry cows ($P < 0.05$, Tukey–Kramer). Heifers did not differ from either lactating or from dry cows (n.s.). Cows in lactation month 12–15 (dry cows) ate less in the paddocks than heifers and cows in lactation ($P < 0.05$).
Fig. 3. Behaviour groups affected by lactation number (LSM ± S.E.) during totally 780 min. observation. Bars with different letters within each behaviour group are significantly different (P < 0.05, Tukey–Kramer). These behaviours do not equal to 100%.

3.2. General activity

The percentage of observations for the different groups of behaviours in the four treatments is shown in Fig. 4. These percentage values were not tested for statistically. The cows that were not exercised spent most of their time in the barn standing and performing eating directed behaviours while the exercised cows were more occupied with walking and trotting, explorative and self grooming behaviours. Social behaviours were also more pronounced among the exercised cows. A lot of the recordings included in the category other behaviours for the non-exercised cows consisted of drinking water and pressing the nose on the feed manger or part of the cross binding.

3.3. Time taken to lie down and milk production

There was no effect of treatment on the time taken to lie down, either in phase 1 (n.s., χ² = 5.04, d.f. = 3), phase 2 (n.s., χ² = 0.99, d.f. = 3) or the total time (n.s., χ² = 5.37, d.f. = 3). Neither did we find any effect of lactation number on the different times taken to lie down (n.s., χ² = 0.39, d.f. = 2). The mean time taken to lie down in the four treatments are shown in Table 2. There were no differences in milk production between the different treatments (n.s., χ² = 1.77, d.f. = 3). The mean milk production for the cows in the herd was 28.1 kg per day ± 1.12 S.E.M.

3.4. Claw measurements and claw lesions

Cows exercised daily (E7) and twice a week (E2) had significantly shorter diagonal than cows not exercised (NoE) (Table 3). The net growth of the toe was least for the cows that were exercised every day. Cows that were exercised once a day and once a week decreased
Fig. 4. The percent of observations spent on different behavioural categories for the different treatments.

their claw angle significantly less than the cows that were not exercised. All exercised cows had significantly lower net growth of the diagonal than the non-exercised cows.

There was a tendency towards lower risk for heel horn erosion in the exercised groups compared to the non-exercised group at trimming in spring (Table 4). The group exercised every day tended to have more laminitis related lesions and dermatitis than the other groups.

Table 2
Mean lying down time in seconds + S.E. for the different phases and groups

<table>
<thead>
<tr>
<th>Lying down</th>
<th>E7</th>
<th>E2</th>
<th>E1</th>
<th>NoE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1 (s)</td>
<td>24.53 ± 3.47</td>
<td>17.37 ± 2.15</td>
<td>28.87 ± 4.6</td>
<td>23.12 ± 3.10 n.s.</td>
</tr>
<tr>
<td>Phase 2 (s)</td>
<td>6.70 ± 0.33</td>
<td>6.64 ± 0.37</td>
<td>6.18 ± 0.29</td>
<td>6.30 ± 0.23 n.s.</td>
</tr>
<tr>
<td>Total (s)</td>
<td>31.23 ± 3.57</td>
<td>24.01 ± 2.19</td>
<td>35.06 ± 4.5</td>
<td>29.43 ± 3.11 n.s.</td>
</tr>
</tbody>
</table>
Table 3
Claw measurements before spring trimming and differences between measurements after autumn and before spring trimming—net growth (LSM and SE)

<table>
<thead>
<tr>
<th>Group</th>
<th>Claw length</th>
<th>Claw angle</th>
<th>Diagonal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before spring trimming</td>
<td>Net growth</td>
<td>Before spring trimming</td>
</tr>
<tr>
<td>E7</td>
<td>85.28 ± 1.83*</td>
<td>15.05 ± 1.73**</td>
<td>42.61 ± 1.58*</td>
</tr>
<tr>
<td>E2</td>
<td>89.94 ± 2.23</td>
<td>19.70 ± 2.00</td>
<td>40.63 ± 1.79</td>
</tr>
<tr>
<td>E1</td>
<td>90.15 ± 2.13</td>
<td>20.36 ± 2.00</td>
<td>44.75 ± 1.85*</td>
</tr>
<tr>
<td>NoE</td>
<td>91.42 ± 1.82</td>
<td>23.03 ± 1.71</td>
<td>37.54 ± 1.54</td>
</tr>
</tbody>
</table>

*P < 0.05; **P < 0.01, comparisons with NoE (Dunnett test).

Table 4
Odds ratios and 95% confidence interval of heel horn erosion, laminitis related lesions, dermatitis and white line fissures at spring trimming for the exercised groups in relation to the non-exercised group

<table>
<thead>
<tr>
<th>Groups</th>
<th>Heel horn erosion</th>
<th>Laminitis related lesions</th>
<th>Dermatitis</th>
<th>White line fissures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>E1</td>
<td>0.73</td>
<td>0.11–4.91</td>
<td>0.48</td>
<td>0.06–3.99</td>
</tr>
<tr>
<td>E2</td>
<td>0.68</td>
<td>0.1–4.73</td>
<td>0.98</td>
<td>0.15–6.45</td>
</tr>
<tr>
<td>E7</td>
<td>0.33</td>
<td>0.05–2.24</td>
<td>1.44</td>
<td>0.26–8.11</td>
</tr>
</tbody>
</table>

However, no significant associations were found because the power of the study was too small (0.25–0.35).

A significant association was found between dirtiness and heel horn erosion (OR = 3.67; 95% CI = 1.16–11.58). Cows from different groups did not differ in dirtiness at the time of trimming (n.s., F = 1.44, d.f. = 3).

4. Discussion

The longer the time the cows had been tied up before they were let out to the paddock the more they walked and trotted, galloped, jumped and bucked in the paddocks. This rebound in locomotion, i.e. a compensatory increase after confinement, has previously been shown in horses with different amount of exercise (Houpt et al., 2001) and in calves and heifers (Jensen, 1999, 2001). The increase in movement with time of confinement could imply that the behaviour is at least partly motivated by internal factors that build up with time (Dellmeier et al., 1985). It can also be argued that the walking and trotting were elicited by the change of the environment, an external factor. Toates (1986) suggests that it is the external stimulus in the context of the animal’s expectation of the environment that triggers explorative behaviour. Then, an increase in explorative behaviour might cause the increase in walking and trotting we found. If this was the only explanation for the increase in movement we would expect to have found the same increase in exploration with time of confinement, but there was only a significant increase between the group exercised every day and both groups exercised less. Krohn (1994) suggests that cows exercised for 1 h daily might fulfil
their need for investigation during the exercise and therefore have a lower level of explorative
behaviours in the stable. In our study we did not observe the exercised cows in the stable so
we cannot compare the amount of exploration for the same cows in different situations. But
comparing our treatments, with Krohn’s (1994) suggestion in the mind, one can hypothesize
that the lack of stimuli in the stable is compensated for by increased exploration when put
in a new environment (outdoor). We suggest that exploratory behaviour to a larger extent is
motivated by the new environment as the paddock represents, and that part of the motivation
for walking, trotting and playing in adult dairy cows is internal and builds up with time of
confinement.

The cows spent a lot of time self-grooming when they were in the paddocks. The cows that
only came out once a week performed more self grooming than the other cows. Especially
the parts of the body that might be difficult to reach when they were tied up were licked.
This was previously observed by Krohn (1994), who reported that cows exercised once
a day licked their hindquarters more during exercise than when tied up. The cows in our
study suffered from mange around the tail base, which also could be an explanation for the
increased licking of the rear parts of the body. Guillot (1981) conclude that the licking of
the body is a way for the cows to decrease the amount of external parasites. From an animal
welfare point of view it is recommended to treat the cows for mange as it also will spread
between animals more easily when exercised. It can be argued that reduced possibilities for
licking impairs the welfare of the cows and regular exercise of tied cows also serves the
purpose of making grooming easier.

Aggressive behaviours, threatening and pushing, were most often performed by the cows
exercised once a week. This type of behaviour is not thought to build up with time since last
performance (Toates, 1986). Aggressive behaviour is thought of as being motivated by the
presence of an opponent and the animal’s past history of encounters (Toates, 1986). Maybe
the cows that were outdoors together everyday, did not regard each other as opponents and
therefore their level of aggressive behaviours was lower than in the other groups that did
not meet each other every day. We suggest that the period between encounters in group E1
might have been too long for the cows to remember each other.

The amount of rumination observed in the different treatments shows a totally opposite
pattern than walking and trotting. The less time the cows spent in the paddocks per week,
the less time they spent ruminating while in the paddocks. In the tie stall there is not so
many things to do other than eat and ruminate so when cows are let out for 1 h a week
they probably don’t spend that time with the same things as in the tie stall. For the cows
that were let out every day, the time available per week for movement, self grooming and
exploration was more than enough, so they spent part of the time outdoors ruminating. A
complementary explanation can be that we let the cows out during a time of day when they
usually ruminated and if this happened every day, as for the cows in treatment E7, they used
this time for ruminating even when they were outdoors.

The cows that were exercised every day lay down during the 1-h of exercise. This was
not found in a previous study, where none of the cows that were exercised daily were seen
lying down during the exercise period (Krohn and Rasmussen, 1990). The cows in our study
always lay down where there was grass and on the highest spot in the paddock. One cow
that interrupted the lying down movements several times in the tie stall lay down outdoors
even when the ground was covered with snow.
In all statistical analysis, the cow was used as the experimental unit, since they were confined individually and all behavioural observations were made on focal animals. However, the cows were exercised as a group and for the exercise treatments the behaviours measured were made in this social context. Therefore, it could be argued that the experimental unit should be the treatment group, at least for behaviours where the cows could influence one another. The results of these behaviours should therefore be treated with caution and a replication of the study would improve our confidence in the findings. We still believe that our observations show treatment differences that are independent of the social context.

Heifers and first calvers explored the environment more, ate more and groomed themselves less than older cows. The explorative behaviour and eating is probably closely connected since the only thing they could have found to eat was old grass on the ground or grass sticking out from the snow. Cows that spent less time exploring did not find this grass. Das et al. (2000) found that six months old calves spent more time performing explorative behaviours than one month old calves, an increase with increasing age. For a young animal it is useful to spend energy and time exploring the environment to gather information but, with increasing age and experience, the less time spent on exploring the surroundings the more time and energy can be spent on foraging. This decrease in information seeking with increasing age has been shown in fowl (Lindqvist, 2003).

The additional exercise did not seem to influence the time taken to lie down. This is supported by Herlin (1994) who found that tied cows that had been kept inside during the summer did not differ in their lying down time from tied cows that had been out on pasture from May until September when recorded in October.

Claw measurements showed that non-exercised cows on rubber mats had longer and lower-angled claws, in comparison to outdoor exercised cows. Non-exercised cows also had a significant longer diagonal than all exercised groups. The diagonal is presumed to be easy to measure accurately with high repeatability (McDaniel, 1997), and is recognised as the most informative claw measurement (Boelling and Pollott, 1998). Both amount of exercise and the quality of the floor are important in their influence on claw conformation. In a study by Vermunt and Greenough (1996) first calving heifers, which were kept outdoors on dirt had longer claws than heifers kept indoors on concrete. The heifers outdoor probably walked more, but the surface was probably less abrasive than the concrete floors indoors. Vokey et al. (2001) and Tranter and Morris (1992) showed that cows with more exposure to abrasive floors generally had higher claw growth and wear rates. The difference in net growth between two of the exercised groups and the control group suggests that exercised cows wore away significantly more of the claw horn than non-exercised cows kept on rubber mats. The difference in significant results between claw length and angle measurements between groups of different exercise frequency could partly be explained by the poorer precision of the traits and a consequence of too small groups. Claw conformation is a result of, but also a risk factor for, claw lesions. Shorter and steeper hind leg claws are generally less prone to be diseased (Politiek et al., 1986; Smit et al., 1986).

Due to the low power of the present study, claw lesions did not show any significant associations with exercise schedules. However, there was a biological relevance in the obtained results, which makes it useful for discussion. The odds for laminitis related diseases (sole haemorrhages, white line lesions) increased at spring trimming in the group exercised every day. This could be a consequence of the higher risk for sole contusions (Ossent et al.,
and abrasions on the hard, uneven surface in the passage way and in the paddocks during winter compared to the rubber mats in the tie-stall. This is also a consistent finding when comparing loose-housed animals on concrete flooring to the dairy cows tied on rubber mats (Bergsten and Herlin, 1996; Manske et al., 2002). Gustafson (1993) reported a similar increase of sole haemorrhages in exercised tied dairy cows. On the other hand, the cows exercised once a week tended to have less sole haemorrhages than the other groups. A possible explanation could be that the cows experienced an efficient exercise once a week while the total time of claw exposure to the unfavourable surface was minimized. Efficient exercise stimulates blood circulation in the feet, provides claw tissue with oxygen and nutrients, and evacuates possible toxins that could prevent the development of laminitis related lesions (Ossent et al., 1997).

Non-exercised cows tended to develop more heel horn erosion and less dermatitis. This is supported by Andersson and Lundström (1981) and Bergsten and Pettersson (1992) who also found tendencies for tied cows to develop more heel horn erosion and less dermatitis during the housing season.

The longer diagonal in non-exercised animals and more heel horn erosion is logical as it indicates a relatively lower heel and more exposure to dirt than animals with a shorter diagonal. A significant association between foot dirtiness and heel horn erosion was found although there were no differences between groups. Cows with little or no exercise spent more time in the tie stall where the claws are more exposed to manure and urine, while cows exercised every day had the opportunity to clean the claws in the paddock. From earlier studies, a significant association between dirty stall environment and heel horn erosion has been clearly shown (Philipot et al., 1994; Offer et al., 2001; Hultgren and Bergsten, 2001, Manske, 2002).

5. Conclusions

We conclude that dairy cows move around more in an outdoor paddock the longer time they have been tied up and that exercise during the winter period does not affect the lying down time for these cows. From the claw measurements and health recordings we conclude that exercised cows wore their claws more and that it was a tendency for more hygienic related lesions and less laminitis related lesions in non-exercised cows.

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