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Foot disorders in dairy cattle: impact on cow and dairy farmer

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Abstract

This paper considers the economic consequences and the welfare impact of foot disorders in dairy cattle and the association between them, taking into account clinical and subclinical foot disorders. In dairy farming with cubicle housing and concrete floors, foot disorders are a major welfare problem with serious economic consequences. On average, foot disorders cost €53 per cow per year, of which indirect cost factors are the main cause. Subclinical foot disorders, which are the foot disorders not recognised by dairy farmers, account for 50% of the total welfare impact and 32% of the total costs. The consequences of foot disorders can be difficult to observe and more insight into these consequences is helpful in stimulating actions to improve dairy cow foot health. Digital dermatitis (DD), an infectious foot disorder, is the most serious foot disorder from both an economic and welfare perspective. The correlation between economics and animal welfare impact suggests that reducing the problem of foot disorders from an economic perspective will positively influence the welfare of dairy cows. Insight into economic and welfare consequences of the different foot disorders, including the association between them, can help make dairy farmers more aware and help with decision-making regarding measures to improve dairy cow foot health.

Keywords: *animal welfare, dairy cattle, economics, foot disorders, modelling, welfare impact*

Introduction

Foot disorders are an important health problem in current dairy farming because of their high incidence, severity and long duration (Clarkson *et al* 1996; Algers *et al* 2009; Frankena *et al* 2009). Foot disorders and the resultant lameness cause serious economic losses for the farmer (Bruijnis *et al* 2010) and are considered to be the most important welfare issue in dairy farming (Anonymous 2001).

Eighty percent of dairy cows kept in cubicle housing systems have at least one foot disorder and approximately one-third become lame throughout a year (Somers *et al* 2003; Frankena *et al* 2009). The majority of the affected cows have subclinical foot disorders (foot disorders which do not cause lameness) (Clarkson *et al* 1996; Espejo *et al* 2006). There is considerable scientific knowledge on causes and ways of remedying the problems, but this has not led to decreases in the prevalence and incidence of foot disorders (Somers *et al* 2003). Programmes to reduce lameness have limited effect, for example, due to lack of compliance by the farmer and veterinarian (Bell *et al* 2009). Increasing dairy farmers' awareness of the costs associated with foot disorders may be one way to encourage them to proactively improve dairy cow foot health management. After mastitis, the health problem in dairy farming that causes the highest annual costs with €78 per average cow in the herd (Huijps *et al* 2008), foot disorders have a substantial economic impact as well; costing on average €53 per cow in the herd (Bruijnis *et al* 2010). Economic motivation is important for dairy farmers to take action, but concerns about animal health and welfare also play a role (Valeeva *et al* 2007). Thus, increasing farmers' awareness of how foot disorders impact on dairy cow welfare could further motivate them to combat such disorders. More insight into economic and welfare consequences of foot disorders helps farmers become aware of the problem and can therefore be a starting point for making improvements.

We have studied the economic consequences and the welfare impact of subclinical and clinical foot disorders in dairy cattle separately. Here, the adopted methodology and main results are summarised, followed by an analysis of how findings on economics and animal welfare are related. Earlier results are integrated to establish whether or not specific foot disorders produce a comparable impact on economics and animal welfare. Such knowledge is relevant, for example, as the different approaches for assessing the consequences of foot disorders can lead to them being prioritised differently based on their impact and lead potentially to mixed messages to the dairy industry.

Materials and methods

Modelling foot disorders

A dynamic simulation model has been developed for estimating the consequences of foot disorders (Bruijnis *et al* 2010, 2011). The model simulates cow characteristics such as the parity, stage of lactation and milk production level all of which influence the probabilities for developing a foot disorder. In the second step, the model simulates the dynamics of foot disorders per cow per month for two years, giving the incidence and duration of the disorders. In the third step, the results of the second year are used to calculate the economic consequences and welfare impact for the simulated foot disorders in one year. The fourth step sums cow level results to produce herd-level results.

Details on the model building and parameterisation are reported (Bruijnis *et al* 2010, 2011), dealing with the consequences of foot disorders for economics and animal welfare, respectively, and here such information is summarised only briefly. Model parameter settings were directed by reports in relevant literature on prevalence, incidence, and consequences of foot disorders in dairy cattle. Only those papers with criteria relevant to common Dutch dairy circumstances were included for estimation of the input values of the model. These criteria include a cubicle housing system with a concrete (slatted) floor, pasturing during summer, two foot-trimming interventions per year and a herd consisting of mainly Holstein dairy cows. These farm characteristics resemble those of many modern dairy farms in other Western countries, and present findings are assumed to describe the situation especially for such farms.

The following foot disorders were modelled: interdigital phlegmon (IP); interdigital dermatitis and heel-horn erosion (IDHE); digital dermatitis (DD); sole haemorrhage (SoH); white line disease (WLD); sole ulcer (SUL); and interdigital hyperplasia (HYP). IP, IDHE and DD are infectious foot disorders; SoH, WLD, SUL and HYP have physical or metabolic causes or are a secondary foot disorder.

Where IP is an acute, painful inflammation, IDHE is an epidermitis of the interdigital skin extending to the dermis up to the heel horn. DD infection affects the epidermis of the hoof skin (Blowey & Weaver 2003). SoH refers to damage of the corium and is classified as haemorrhage in the sole, being reported in literature under different names like subclinical laminitis and laminitis. WLD identifies haemorrhages and lesions in the white line. SUL mainly occurs after SoH and IDHE and is about ulcers in the sole, toe and heel. HYP is proliferation of the interdigital skin and originates as a reaction to long-lasting inflammation (eg DD and IDHE). It is assumed that all cases of IP and SUL occur clinically. For most of the simulated foot disorders (IDHE, DD, SoH, WLD and HYP), it is assumed that the foot disorder first occurs subclinically (see Table 1 for the definition of 'subclinical') before developing into a clinical foot disorder. The modelling followed the scheme as presented in Figure 1. In the model, every month each cow has a different probability of changing foot health status, depending on their status in the previous month: development of a foot disorder, transition from a subclinical to a clinical foot disorder or cure from a foot disorder. Getting a foot disorder is set by the probabilities of transition from healthy to subclinical (P_{HS}) or to clinical (P_{HC}). These are influenced by parity, stage of lactation and milk-production level. For example, a higher producing cow has a higher risk of getting a foot disorder. The subclinical foot disorders have a probability of developing into the clinical phase after one or more months (P_{SC}) or have a probability of cure after foot trimming (P_{SH}). The clinical foot disorders have a certain probability of recovery due to treatment by the farmer, foot trimmer or veterinarian during the year or after foot trimming (P_{CH}) and a probability of culling due to the foot disorder (P_{CUL}). The state of the cow, 'healthy', 'subclinical', 'clinical' and 'culled', are determined with a set of discrete distribution functions. P_{CUL} is influenced by milk-production level and parity. For each month a cow has a foot disorder, the economic and welfare impact is calculated as described in the following paragraphs.

Economic impact

The total costs due to foot disorders consist of costs due to subclinical foot disorders and clinical foot disorders. The following set of cost factors have been used to calculate economic impact for each month a cow has a foot disorder: milk-production losses, prolonged calving interval, culling, dairy farmers' labour, foot trimmer, veterinarian, treatment, and discarded milk. All cost factors were used to calculate the losses for the clinical cases. Only milk production losses and prolonged calving interval were used as a cost factor for losses due to subclinical foot disorders, where the impact of subclinical losses is estimated to be lower than the impact of the clinical cases. The cost factors apply to the common Dutch situation as modelled, see Bruijnis *et al* (2010).

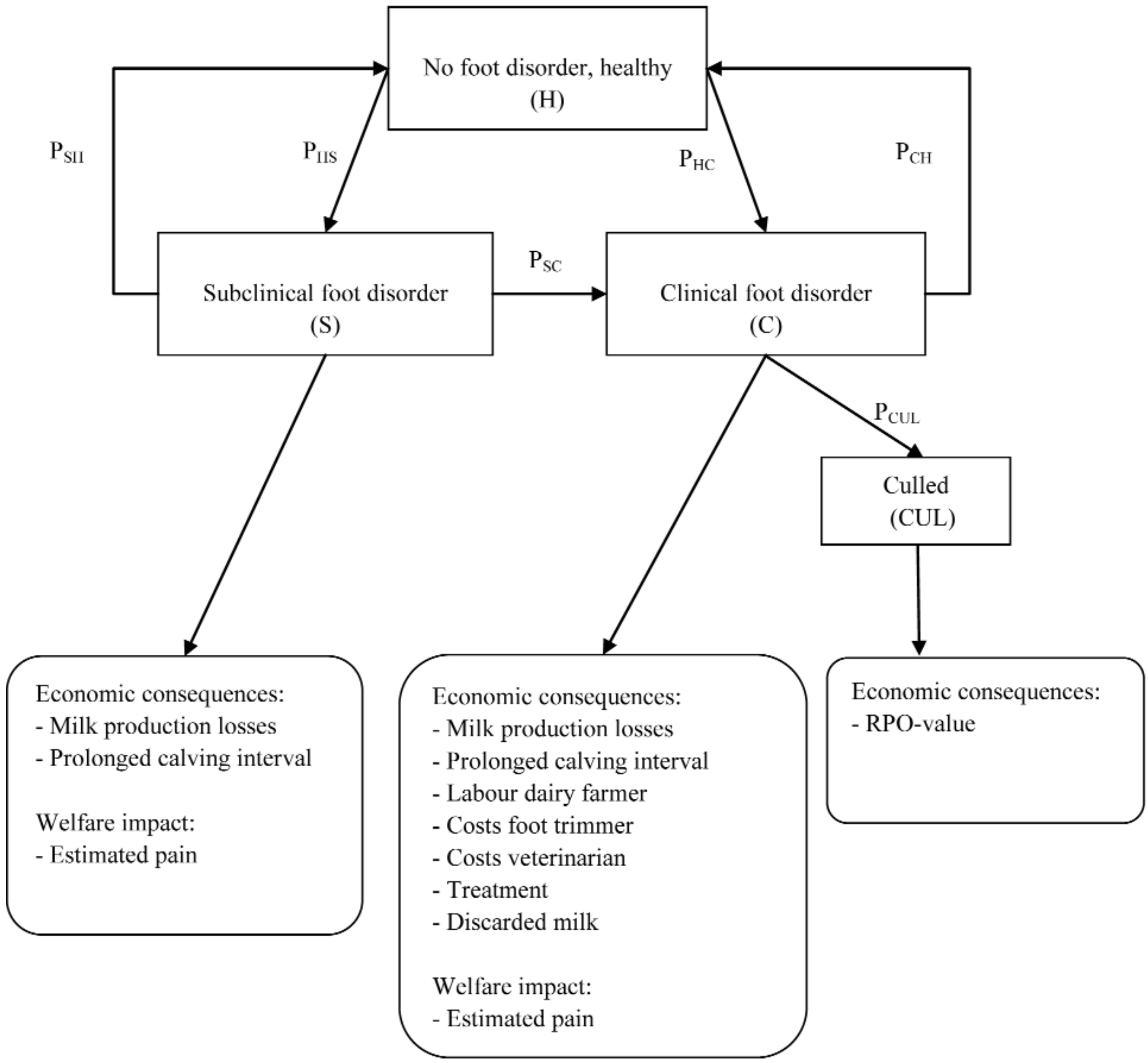
Welfare impact

The welfare impact was assessed using the estimated pain of each foot disorder, assuming that pain caused by the foot disorders is the basis for the effects on the different aspects of animal welfare as defined by Fraser *et al* (1997). Specifically, a cow with a foot disorder will, to a certain extent, have difficulties functioning normally because the pain obstructs locomotor function, causes negative affective states and impairs ability to perform natural behaviours, constraining natural living. Pain impact for each of the foot disorders in clinical and subclinical state, was estimated according to a scoring scale, that is similar to that used in locomotion scoring based on, for example, Bicalho *et al* (2007) and Garbarino *et al* (2004) (Table 1). Literature on pathophysiology of foot disorders and on lameness and locomotion was studied and, in combination with the estimation of experts in the field of dairy cow foot health, the pain impact of a foot disorder in subclin-

Table 1 Scoring scale used to assess the pain impact of different foot disorders. Scores 1 and 2 represent subclinical foot disorders (visible as subtle changes in gait and can be diagnosed during inspection of the feet), scores 3, 4 and 5 represent clinical foot disorders, which cause lameness.

Score	Locomotion and estimated pain level
1	Presence of a slightly asymmetric gait, discomfort
2	Presence of an asymmetric gait, severe discomfort
3	The cow clearly favouring one or more limbs, moderately lame, pain
4	Severely lame, severe pain
5	Extremely lame, non weight bearing lame, very severe pain

Figure 1



Schematic representation, adjusted after Bruijnis *et al* (2010) of how the foot health status of the cows is determined in the simulation model, including the factors used to calculate the economic consequences and welfare impact. P_{HS} = probability transition from healthy to subclinical; P_{HC} = probability transition from healthy to clinical; P_{SH} = probability transition from subclinical to healthy; P_{CH} = probability transition from clinical to healthy; P_{SC} = probability transition from a subclinical foot disorder to a clinical foot disorder, and P_{CUL} = probability of culling.

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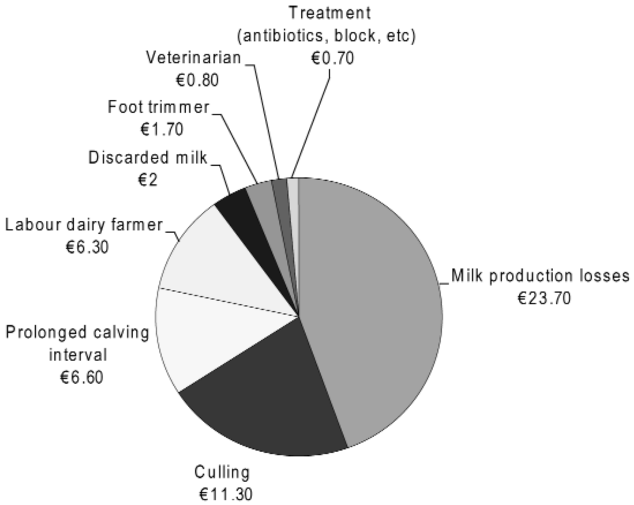
Figure 2



Economic consequences (€ per year) of foot disorders on the default farm: cubicle housing with concrete (slatted) floor, pasturing during summer (April through September), two foot trimming interventions per year (in April and October), classified by cost factors.

Table 2 Average pain impact, on a scale of 1 to 5, for the different foot disorders by subclinical (SC) and clinical (C) cases based on expert estimations and literature study.

Pain		IP[1]	IDHE[1]	DD[1]	SoH[1]	WLD[1]	SUL[1]	HYP[1]
Score	SC	–	1.1	1.3	1.0	0.9	–	1.6
	C	4.9	3.3	3.4	3.1	3.5	3.9	2.9

[1] IP = Interdigital phlegmon; IDHE = Interdigital dermatitis and Heel-erosion; DD = Digital dermatitis; SoH = Sole haemorrhage; WLD = White-line disease; SUL = Sole ulcer; HYP = Interdigital hyperplasia.

ical and clinical state was estimated. The welfare impact was calculated by counting this pain score for each month the foot disorders were present (see Bruijnis *et al* 2012).

Correlation

Using the statistical software package SAS (version 9.1), a Spearman rank correlation coefficient between economic consequences and welfare impact outcomes was calculated to study the correlation between them.

Results

Pain impact for the different foot disorders varies. The subclinical forms of foot disorders are scored as causing discomfort or severe discomfort (scores 1–2), as it is not expected that they will cause lameness but only subtle changes in gait and can be diagnosed by inspection of the feet. The clinical forms are scored as causing pain to very severe pain (scores 3–5; Table 2). Of all the foot disorders, IP is estimated to be the most painful when present.

The total costs due to foot disorders (€53 per cow per year) are divided between the costs that are direct (treatment, veterinarian, foot trimmer, dairy farmers' labour) and those that are indirect (discarded milk, prolonged calving interval, culling). Milk-production losses are highest, comprising 44% of the total costs due to foot disorders, followed by culling (22%), prolonged calving interval (12%) and costs for extra labour of the dairy farmer (12%) (Figure 2). Treatment costs and costs for a veterinarian or foot trimmer cause the lowest costs on yearly basis.

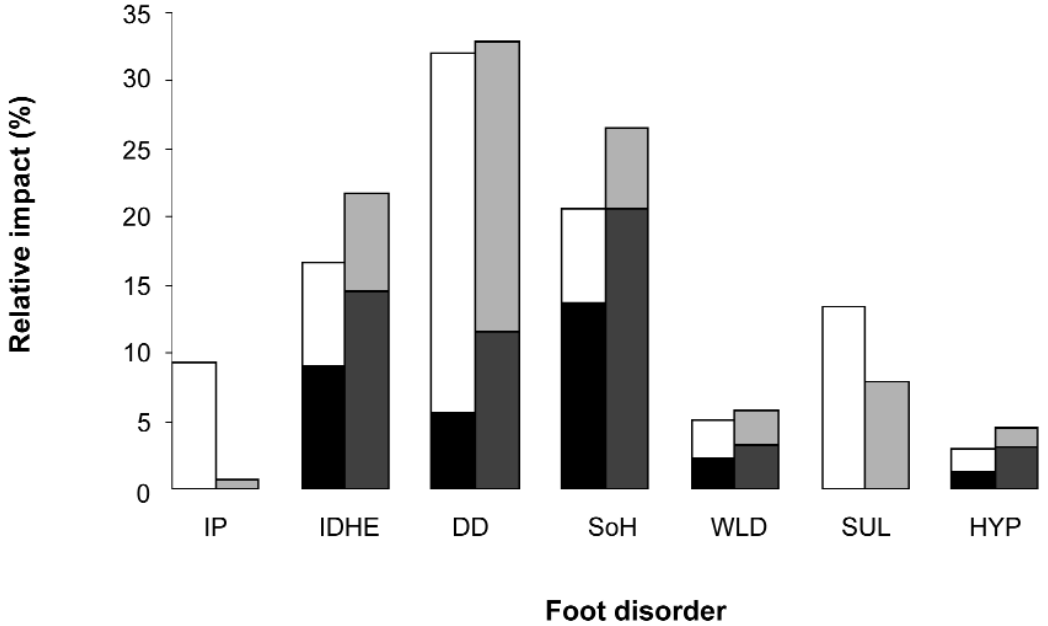
By comparing economic consequences and welfare impact outcomes, subclinical cases make up 32% of all costs and account for approximately 50% of the welfare impact. Digital dermatitis, has the highest impact: almost one-third of total impact for both economics and welfare (Figure 3). Sole haemorrhage and interdigital dermatitis/heel erosion, mainly subclinical and of a high prevalence, have a substantial impact on costs due to foot disorders, 20 and 17%, respectively, and on welfare, 27 and 22%, respectively. Interdigital phlegmon, the foot disorder regarded as most painful (Table 2), but which has a low incidence and short duration, is not very costly, accounting for only 10% of total costs, and has the lowest welfare impact, 0.5%. Together with SUL, IP only occurs clinically and has a relatively higher impact on economics than on welfare (Figure 3).

The outcomes on economics and welfare impact are significantly positively correlated, with a Spearman rank coefficient of 0.64 ($P < 0.05$). Subclinical cases of foot disorders tend to have a relatively higher impact on welfare than the clinical cases (Figure 4).

Discussion

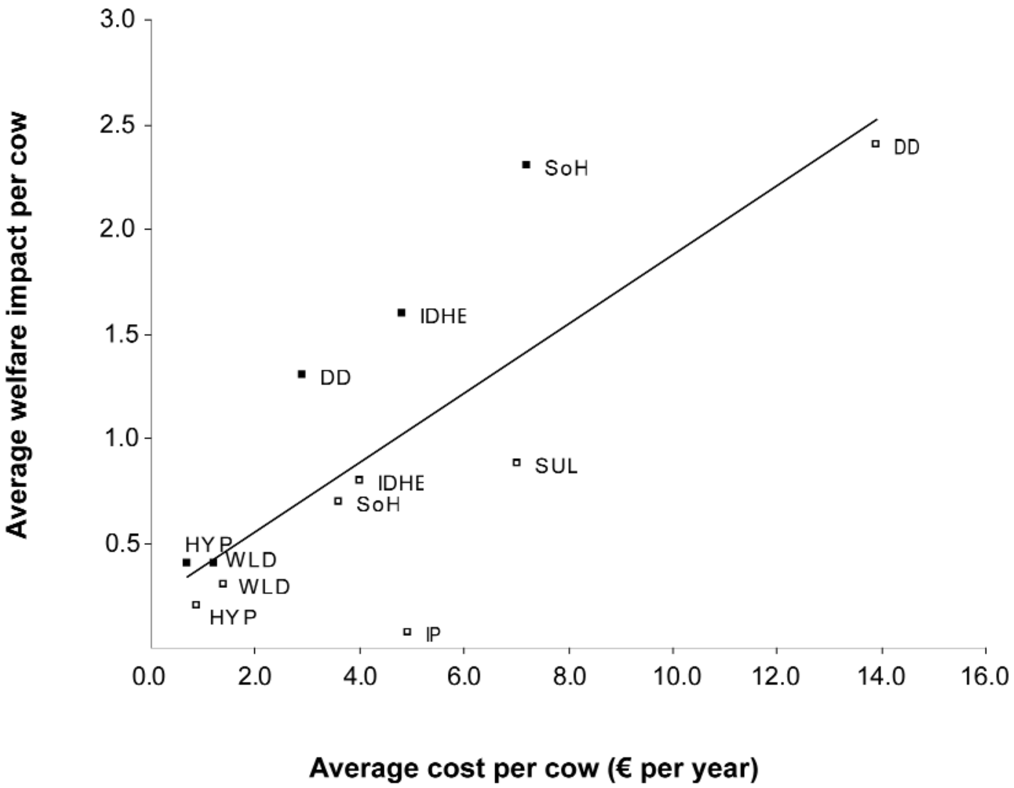
Our results describe how specific foot disorders impact on economics and dairy cow welfare, reflecting the different impact of the foot disorders in terms of painfulness, duration and incidence. These outcomes apply to the modelled situation: a common Dutch dairy farm with cubicle housing with a concrete floor, mainly Holstein Friesian dairy cows and pasturing during summer. In our study, foot disorders are classified as subclinical or clinical based on knowledge about pathophysiology and estimated locomotion score. An important difficulty for this assessment is that there is much variety in diagnosis of the different foot disorders and their severity (eg Holzhauer *et al* 2006). The literature study, performed to gain more specific information about foot disorders and the effects on pain and welfare, revealed the lack of such information for specific foot disorders in the subclinical and clinical states. At first, we wanted to include information about the effects of different gradations of foot disorders on behaviour, and the consequences thereof, to make a specified estimation about their impact on dairy cow welfare. The literature study revealed that studies look mostly at lameness, without distinguishing between type of foot disorder, severity and effects on behaviours like walking, lying, eating, etc. Although some studies have looked at different foot disorders, eg Manske *et al* (2002) and Tadich *et al* (2010), effects on behaviour and long- versus short-term effects

Figure 3



Relative impact at the herd level for each foot disorder of the economic consequences and welfare impact, divided for the clinical economic consequences (white bars), sub-clinical economic consequences (black bars), clinical welfare impact (light grey bars) and sub-clinical welfare impact (dark grey bars). IP = Interdigital phlegmon; IDHE = Interdigital dermatitis and Heel erosion; DD = Digital dermatitis; SoH = Sole haemorrhage; WLD = White line disease; SUL = Sole ulcer; HYP = Interdigital hyperplasia.

Figure 4



Relationship between average costs and the welfare impact per cow in the herd over one year by clinical (□) and subclinical state (■). The Spearman rank correlation is 0.64 (P < 0.05). IP = Interdigital phlegmon; IDHE = Interdigital dermatitis and Heel erosion; DD = Digital dermatitis; SoH = Sole haemorrhage; WLD = White-line disease; SUL = Sole ulcer; HYP = Interdigital hyperplasia.

were not reported. Furthermore, of the studies looking at effects on behaviour, some confirmed that an increased locomotion score had an increasing impact on functional (milk production) and behavioural (eg eating frequency) effects (eg Bach *et al* 2007), but most studies only distinguished between lame and non-lame (eg Walker *et al* 2008). Moreover, the importance of duration and relative importance of different behaviours could not be derived from the literature. Such specific information could have given a more accurate idea about the impact on and importance of different aspects of welfare (functioning, feeling and natural living) and the weighing of different parameters (especially the relation between pain severity and duration).

The calculated Spearman rank correlation of 0.64 shows there is a positive correlation between economics and welfare. Some foot disorders have a greater economic impact, others a greater impact on welfare. Figure 4 points out, for example, that the clinical occurring foot disorders IP and SUL have a relatively higher economic, rather than welfare, impact. The duration of these foot disorders is relatively short, because obvious clinical cases will be treated more promptly and thoroughly than subclinical or mild clinical cases. Duration and incidence of foot disorders play an important role when determining the economic and welfare impact of foot disorders; subclinical foot disorders IDHE and SoH are scored as having a high welfare impact because affected animals suffer from these for a long period of time. It could be that for these foot disorders the welfare impact is overestimated because of a lack of specific knowledge on the effect of foot disorders in their differing severities. The impact of the clinical states could be more severe compared to the long-lasting subclinical states than estimated here. The total impact of a secondary foot disorder like SUL could be underestimated as well, because when this foot disorder is present, the cow already probably has suffered from SoH or IDHE, both of which impair welfare and affect the abilities of a cow.

The results in this study apply to a common Dutch dairy farm, these specified conditions influence the estimations for impact of foot disorders on welfare and costs, and different management or specific farm conditions will lead to different estimations. This explains why, for example, our cost calculations differ from previous calculations in The Netherlands (Enting *et al* 1997), the UK (Kossaibati & Esslemont 1997), Denmark (Ettema & Østergaard 2006) and US (Cha *et al* 2010). Furthermore, these studies used a different approach and all focused on separate cases of clinical foot disorders (ie causing lameness) and did not include the costs for an average cow in the herd. Another aspect that can influence the results relates to the assumptions about the cost factors. An illustrative example concerns milk-production losses incurred by foot disorders and lameness. Many different studies have been executed with varying results, reporting, for example, production losses for DD and more than 10% losses for SUL (Amory *et al* 2008) compared to a study where DD had higher milk-production losses than SUL (König *et al* 2008). Moreover, differences in foot-disorder-specific milk-production losses differ between herds (Warnick *et al* 2001).

Lame cows and cows walking tenderly were classified as lame cases. Dairy farmers detect lameness less frequently than researchers (Espejo *et al* 2006), which is problematic as the consequences of foot disorders that remain undetected by the farmer, and thus untreated, are considerable. At herd level, the welfare impact of subclinical foot disorders is 53% of the total welfare impact and one-third of the economic consequences. The known underestimation of foot-disorder-associated problems by dairy farmers (Leach *et al* 2010) is in line with our findings that subclinical foot disorders (not easily recognised) and indirect cost factors are important for the impact of foot disorders. Foot disorders have serious consequences for the dairy cow and farmer; costing the farmer on average €53 per cow (Bruijnis *et al* 2010), compared to the €78 per average cow in the herd for mastitis (Huijps *et al* 2008), and having a serious impact on the cow's welfare (Bruijnis *et al* 2011). The positive correlation between economic consequences and welfare impact provides evidence that taking measures to reduce the costs due to foot disorders will simultaneously improve the welfare of dairy cows, too. The extent to which dairy farmers are stimulated to take action depends on their personal preferences. A dairy farmer, valuing welfare improvements, could be given extra motivation to follow through with change when provided with information about the correlation between welfare and economics. It can also support decisions on which measures to prioritise. Measures which work mostly on the foot disorders with a relative high welfare impact are more likely to be preferred by farmers attaching a higher value to welfare. Furthermore, which measures are prioritised does not only depend on the possible gain in economics and animal welfare, but also on the measures which need to be taken. Dairy cow foot health can be improved through a number of different intervention measures, each measure improves foot health status in its own way and asks for different types of investment. Some measures can be a long-term investment, like the use of rubber flooring instead of concrete flooring or investing in a manure robot to reduce slipperiness and increase the hygiene of the floor. Both these measures can improve foot health (Kujala *et al* 2009; Ouweltjes *et al* 2011), but the amount of investment, their payback time and cost effectiveness will differ. Moreover, the effect on dairy cow welfare differs between investments. The application of rubber flooring improves dairy cow comfort, while other measures do not have a direct positive on cow comfort, like footbathing. Next to the long-term investment, an intervention measure may require a change in daily routine, like checking the cows more frequently and treating the cows promptly and thoroughly. Huijps *et al* (2009) has shown that dairy farmers can prefer measures which are less cost effective but that require minimal labour efforts.

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Animal welfare implications

Insight into the economic and welfare consequences of different foot disorders can help provide an insight into the impact of foot disorders, increasing dairy farmer awareness. Moreover, the relationship between economics and welfare can help to prioritise approaches to improve dairy cow foot health.

Conclusion

In Dutch dairy farming with cubicle housing and concrete floors, foot disorders are a major welfare problem with serious economic consequences. At the herd level, DD has highest impact on economics and cow welfare, followed by SoH and IDHE. Subclinical foot disorders, which are the foot disorders not recognised by dairy farmers, account for 50% of the total welfare impact of foot disorders and 32% of the total costs, indicating a considerable impact of undetected or untreated foot disorders. Combined with the fact that the indirect cost factors (eg milk-production losses) are the most important cost factors, the underestimation of foot health problems by dairy farmers can be explained (partly). The impact of foot disorders on economics and animal welfare are positively correlated, a finding which can further increase awareness among farmers and stimulate improvements in dairy cow foot health. Personal preferences relating to the importance of animal welfare, economic profit, labour circumstances, etc, determine the prioritisation to take measures. Information on how foot disorders impact on these different aspects can assist farmers in making reasoned decisions on which measures to take.

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