Recording of claw and foot disorders in dairy cattle: current role and prospects of the international harmonization initiative of ICAR

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Abstract

Claw and foot disorders causing lameness are among the major culling reasons in dairy cattle around the world and play a significant role in farm profitability and compromised animal welfare. In recent years, several countries have started routine recording of claw health data. Documentation of claw health status during regular claw trimming has been identified as a valuable source of information on feet and legs conditions in individual cows and can also provide an important insight into the health status of the entire herd or population. However, heterogeneous documentation practices complicate the routine collection of claw health data and consequently the use of the data. To document the current situation of recording and the use of claw health data among ICAR member countries, the ICAR Working Group for Functional Traits (ICAR WGFT) carried out an online-survey during August and September 2014. Responses from 18 countries showed that around half of them have a single national key for recording claw and foot disorders.

Information is collected on 6 to 20 different disorders, in many cases including severity grades using numeric or descriptive recording and affected sites. Professional claw trimmers were found to be the main source of data collection, often using hand-held electronic recording devises and customized software. Digital dermatitis, white line disease, sole ulcer, interdigital phlegmon (foot rot);interdigital hyperplasia (corns), and sole hemorrhage are among the most commonly recorded disorders. Routine genetic evaluation for claw health has been implemented in the Nordic countries in 2010 (Denmark, Sweden and Finland) and Norway (2014). Since 2010, the Netherlands has published breeding values for claw health. Other countries including Canada, Spain, and France have successfully set up recording schemes for claw health information. Other countries also have plans to initiate projects. To be able to make comparisons of claw health between countries and for breeding purposes, the harmonization of the terminology of claw disorders is advantageous. Since May 2014, ICAR WGFT has been engaged in a collective effort involving international claw health experts and interdisciplinary collaborators to develop harmonized definitions for claw disorders along with representative photographs of each disorder. The focus is on descriptive findings. The objective is to establish an international claw health atlas which can guide future developments towards better claw health data that can be used to improve management and breeding of dairy cattle.

This paper provides an overview of the recording of claw and foot disorders in dairy cattle with a focus on aspects of breeding and presents the results and prospects of the work of the ICAR WGFT and international claw health experts on harmonization of terminology and definitions of claw disorders.

Key words: claw health, harmonization, claw disorders, genetic evaluation.

Introduction

Along with reproductive- and udder health problems, foot and claw disorders are major reasons for involuntary culling in dairy cattle. Culling caused by lameness problems accounts for 10-15% of all culls and shows the economic importance of this trait complex (Green *et al.*, 2002; ADR, 2009; Bruijnis *et al.*, 2010; Cha *et al.*, 2010). In general, there are negative genetic correlations between milk yield and functional traits and because of this, an increase in incidences of lameness may be expected worldwide (Veerkamp *et al.*, 2003; Gernand *et al.*, 2012). German figures have shown this unfavorable trend in lameness and involuntary culling over the last decades (ADR, 1980-2009).

According to Van der Waaij *et al.* (2005) more than 70% of cows in The Netherlands have at least one claw disorder. The study is based on data from routine claw trimming over a period of 1.5 years. Rouha-Mülleder *et al.* (2009) found an incidence rate of lameness of 36% in the average of 80 dairy herds in Austria reported variation of 0 to 77% between herds during two consecutive visits. Hoof lesions compromise the welfare of animals (Whay *et al.*, 2003) and coincide with reduced milk yield (Warnick *et al.*, 2001; Amory *et al.*, 2008), reduced fertility (Hernández *et al.*, 2001; Meléndez *et al.*, 2003) and an increased risk of premature culling (Rajala-Schultz and Gröhn, 1999; Booth *et al.*, 2004). Studies estimate a loss of up to 450 Euro per lame cow per year. According to Cha *et al.* (2010), 38% of the loss of $216 (US) due to sole ulcer is because of lower milk yield; 42% of the $120 (US) costs for digital dermatitis are due to labor costs and 50% of the costs of interdigital phlegmon are due to reduced reproductive performance.

Foot and claw disorders are often accompanied by pain and are therefore a major animal welfare issue. According to EFSA (2012) a maximum of 10% lame cows with a lameness score of 2 or higher is tolerable. Weber *et al.* (2013) suggested that lameness might be a useful indicator for claw and leg health. The conformation of feet and legs are recorded routinely by linear type classification systems that are often part of the services offered by breeding societies and some traits may be useful indicator traits for claw health. Although they cannot replace direct measures of claw health, because of low genetic

correlations with claw disorders, routinely collected conformation data can be used to increase the reliabilities of estimated breeding values (EBVs) (Häggmann and Juga, 2012; Chapinal *et al.*, 2012).

In addition to the information from claw trimming, veterinary diagnoses are potentially valuable sources of information, particularly for more severe cases. Genetic studies on foot and claw disorders have shown the advantage of using direct claw health data when breeding for improved claw health (Linde *et al.*, 2010; Koenig and Swalve, 2006), and heritability estimates were generally higher when data from claw trimming were used (Koenig *et al.*, 2005; Boelling *et al.*, 2008; Laursen *et al.*, 2009; Linde *et al.*, 2010). Boelling *et al.* (2008) suggested an index where the different relevant data sources are combined. For effective improvement of the feet and legs complex by breeding, it is important to establish systems that allow the collection of comparable data from claw trimmers.

Standardization of the terminology of foot and claw disorders within and across countries supports activities including genetic evaluation. International cooperation is an important way to support the development of genetic evaluations for novel traits with limited numbers of phenotypes. For example, there has recently been success in pooling dry matter intake data from 9 countries for genomic prediction purposes (de Haas *et al.*, 2015). A survey on the needs of ICAR member countries regarding functional traits showed that there is substantial interest in the feet and legs trait complex and claw health traits (Stock *et al.*, 2012). Establishing a working group with international experts on claw health and assessing the situation in the different countries was an obvious first step towards global harmonization. A meeting was held in May 2014 in conjunction with the ICAR annual meeting in Berlin, Germany to lay the groundwork for such an initiative. Subsequently, a survey on the status of recording of claw health data in the different ICAR member countries was conducted. Based on the needs of international harmonization of foot and claw disorders, the ICAR WGFT and international claw health experts began working on the harmonization of descriptions of foot and claw disorders in October 2014 and this global collaboration concluded with the publication of the ICAR Claw Health Atlas in June 2015.

Survey on recording of foot and claw disorders

To better understand the current situation on claw health and feet and legs disorders in the different member countries of ICAR, a survey using a questionnaire was conducted from mid-August to the end of September 2014. The overall response rate among the 53 ICAR member countries was 60 percent, with answers to all questions from 18 countries and partial information from further 14 countries.

Harmonized key of claw disorders by country

Using the information from these questionnaires about harmonized key of claw disorders, 10 countries (Denmark, Finland, France, Germany, Israel, Norway, Spain, Sweden, The Netherlands, United Kingdom) reported that they each have a single key on claw disorders and leg conditions used throughout the country. Countries using a single key collect information on 6 to 20 different disorders. The level of information collected on foot and legs conditions varies widely from cow level information (2 countries) to single claw information (4 countries); others gathering information at the cow leg level (9 countries).

In addition to claw lesion information, several countries also record information on severity grades using numeric (1 = mild, 2 = moderate, 3 = severe) or descriptive codes (mild, moderate, severe) of the lesions observed.

Eight countries (Australia, Austria, Canada, Czech Republic, Italy, Poland, Slovenia, United States) have no key for data recording. The absence of a key does not mean that there is no effort to collect information; for example, electronic devices are used by trimmers in Austria, Canada and the United States to collect information that stays at the farm level.

Which disorders are recorded?

For the 18 countries that use a single key for recording claw disorders, Figure 1 shows the frequency of different claw disorders White Line Disease (WL), Sole Ulcer (SU), Interdigital Phlegmon (IP), Interdigital Hyperplasia (IH) and Digital Dermatitis (DD) are the most frequently recorded lesions (12 countries). Sole Haemorrhage (SH) is recorded in 10 countries, followed by Heel Horn Erosion (HHE) and Double Sole (DS) in 9 countries.

Other disorders recorded in several countries are horn fissures (horizontal, vertical, axial), Digital Dermatitis associated with White Line Disease, and Digital Dermatitis associated with Sole Ulcer. In most cases the most frequently recorded lesions across countries are also those claw disorders ranking with the highest priorities. However, regional differences were observed. For example, in Australia wall cracks (Axial Horn Fissure (HFA)) are the 2nd most important lesion, whereas wall cracks are not mentioned in any other country under the most frequent lesions. A similar observation is Corkscrew Claws (CC), which is of high relevance in Norway and Finland.

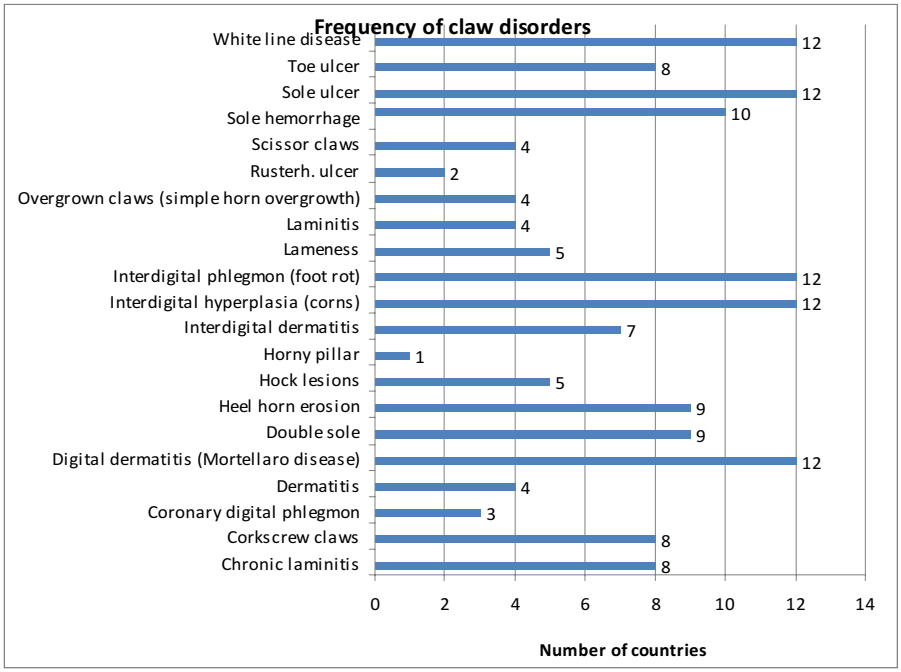

Figure 1. Frequency of the claw disorders most often recorded.

Education and training of claw trimmers

The survey revealed that claw trimmers are the main source for the collection of information and events on these specific dairy cattle disorders in most countries. As veterinarians mainly intervene at the farm when cases are severe, they represent an incomplete source of information for claw health. It is estimated that 40-60 % of claw trimming is done by professional claw trimmers in most of the countries (Austria, Canada, Germany, Italy, Netherland, Norway, Sweden, United Kingdom).

In countries including Finland, and France, 60-80% of the trimming is by professional claw trimmers. In Denmark, Israel, and Spain 80-100% of claw trimming is done by professionals. In countries including New Zealand and Australia, where cows are on pasture most of the year, claw trimming is not a standard practice on most farms.

Trimming also is done by people who have not received special, such as dairy farmers. In some countries (Austria, France, Germany, Italy, Sweden, Finland and Norway, trimmers are licensed and / or certified. In other countries (Canada, Denmark, Finland, Israel, Spain, The Netherlands or United Kingdom) claw trimmers are provided with either special education programs or training by experts. Most of the trimmers use an illustrated guide for the identification of lesions which includes pictures and definitions. As most countries do not have a national scheme to collect information about the people doing this work, it is often difficult to figure out the exact proportion of professional trimmers that are involved.

Some countries with established infrastructures to collect and store data from claw trimming centrally for breeding purposes also organize regular training sessions, or undertake other measures to ensure comparability of the results between the different claw trimmers (e.g. Charfeddine, 2014; Van Pelt, 2015).

Recording practices

The conditions and circumstances of claw care differ widely across countries. The percentage of trimmings recorded by professional trimmers varies. For large farms, claw care is generally carried out by farm staff, professional claw trimmers, or the farmers themselves. It is interesting to note that there are many different tools used to record information on claw disorders and foot and leg conditions, including individual free-text notes (no standardized form), standard forms with reference to the key for claw health on paper sheet reports, free-text or standard forms on mobile electronic devices, and herd management software. The tools most widely used among countries are electronic devices and either mobile or herd management software (11 countries), followed by formatted paper sheet reports (5 countries). In most cases a mixture of recording practices coexist. Despite the different tools available for data recording, it is assumed that many claw trimmings are not documented at all. No exact figures about the documented and centrally recorded claw health information relative to the percentage of dairy cows under milk recording agencies are available. In countries with routine genetic evaluations for claw health, data from claw trimming are stored in a central database and also are used for herd management recommendations. A key aspect of the successful initiatives to build routine genetic evaluations for claw and leg health is the development of an infrastructure for electronic documentation and recording of claw trimming data (Kofler *et al.*, 2011, 2013; Nielsen, 2014; Van Pelt, 2015). Kofler (2013) published an overview of computerised claw trimming database programs which were currently available worldwide.

Status of genetic evaluation for claw health

The current status of the collection and use of claw trimming data from different countries was presented at the 2014 ICAR annual meeting in Berlin *(www.icar.org/Documents/ Berlin_2014/ functional_traits_meeting.htm)*. The status of such system varies widely internationally. Routine genetic evaluations for claw health have been implemented in Denmark, Sweden, and Finland since 2010, and since 2014 they have published genomic breeding value for claw health. 10,000 genotyped cows with phenotypes were included in the genomic reference population (Johansson et al, 2011; NAV, 2014). Norway has published breeding values for claw health since 2014 (Odegard et al, 2013). The Netherlands have published breeding values for claw health since 2010 and Spain and France have successfully managed to set up an infrastructure to capture claw trimming data (25-30% of cows) (Charfeddine, 2014; Thomas and Leclerc, 2014). In other countries claw trimming information have been collected from commercial dairy farms for research projects purpose (e.g. Canada, Germany). In summary, the survey indicated that many activities and projects are under way.

International harmonization of foot and claw disorders

The survey and presentations at the ICAR WGFT meeting in Berlin showed that several countries have recently introduced electronic systems to routinely record foot and claw, and many more are planning or have committed to begin recording in the near future. The broad range of recording practices and documentation schemes with mixture of descriptive and etiological codes has suggested a need for a standardized, practice-oriented approach that accommodates most common circumstances in the field. This motivated the ICAR WGFT to prioritize foot and claw health and to invite internationally recognized claw experts to collaborate in the development of best practices for data recording. This collaboration was intended to complement existing research on specific aspects of the claws and feet of dairy cattle, focusing solely on the standardization and harmonization of data recording. This fruitful interdisciplinary collaboration among experts from different backgrounds (claw health experts, claw trimmers, bovine practitioners, geneticists) resulted in harmonized descriptions of 27 different lesions, providing comprehensive coverage of theoretical and applied needs. It is designed to provide a universal tool for claw trimmers and practitioners and presents guidelines for the recording of important conditions affecting the claw health of cattle. Descriptive trait definitions are used to ensure that accurate classifications are made, which will support the collection of comparable and high-quality data within and across countries to support many activities (e.g., genetic evaluation purposes).

ICAR Claw Health Atlas

After the harmonized descriptions of foot and claw disorders were agreed upon by the international experts and members of the ICAR WGFT, the next step was the collection of representative photographs of each lesion in the key. Claw experts, trimmers, veterinarians, and other contributors submitted photographs, and the most representative examples were selected by voting. The results were discussed and the final selections made by the working group. Harmonized descriptions, photographs, and other descriptive information were assembled to create the first ICAR Claw Health Atlas (Egger-Danner *et al.*, 2015). This Atlas, published in the official ICAR language (English), will be available for translation by any country that would like to distribute it to its professionals and / or farmers. Information about translation and access to a print-quality version will be provided by ICAR. An on-line English-language version will be available on the ICAR website once it is approval by the ICAR member countries: *ww.icar.org/Documents/ ICAR_Claw_Health_Atlas.pdf*.

Conclusion

The ICAR Functional Traits Working Group has focused on a range of very important traits in dairy cattle including: fertility, udder health, and feet and legs. This work is part of ICAR's strategy for helping its members to provide better services to farmers and to facilitate the genetic improvement of farmed livestock, particularly dairy cattle.

For the first time there is an international atlas and coding system available for claw traits in dairy cattle. This represents a major step forward in ensuring that the incidence of claw defects affecting animal health, welfare, and productivity can be reduced in the future.

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List of references

ADR (Arbeitsgemeinschaft Deuscher Rinderzüchter e.V). 1980-2009. Annual Statistics. German Cattle Breeders Federation, bonn, Germany.

Amory, J.R., Z.E. Barker, J.L. Wright, S.A. Mason, R.W. Blowey and L.E. Green. 2008. Associations between sole ulcer, white line disease and digital dermatitis and the milk yield of 1824 dairy cows on 30 dairy cow farms in England and Wales from February 2003?November 2004. Prev. Vet. Med. 83:381-391.

Boelling, D., V.M. Laursen and T. Mark. 2008. Claw Trimming Records and Locomotion Can Improve Selection for Feet and Legs. 59rd Annual Meeting of the Association of European Animal Production, August 2008, Vilnius, Lithuania.

Booth, C. J., L.D. Warnick, Y.T. Gro¨hn, D.O. Maizon, C.L. Guard, and D. Janssen. 2004. Effect of lameness on culling in dairy cows. J. Dairy Sci. 87: 4115-4122.

Bruijnis, M.R.N., H. Hogeveen and E.N. Stassen. 2013. Measures to improve dairy cow foot health: consequences for farmer income and dairy cow welfare. Animal 7(01): 167-175.

Cha, E., J.A. Hertl, D. Bar, and Y.T. Gröhn. 2010. The cost of different types of lameness in dairy cows calculated by dynamic programming. Prev. Vet. Med. 97: 1, 1-8.

Chapinal, N., A. Koeck, A. Sewalem, D.F. Kelton, S. Mason, G. Cramer and F. Miglior, 2013. Genetic parameters for hoof lesions and their relationship with feet and leg traits in Canadian Holstein cows. Journal of Dairy Science 96, 2596-2604.

Charfeddinne, N. 2014. Recording of hoof trimming data in Spain. ICAR-Treffen Berlin, Mai 2014. *www.icar.org/ Documents/Berlin_2014/functional_traits_ meeting.htm*.

de Haas, Y., Pryce, J.E., Calus, M.P.L., Wall, E., Berry, D.P., Løvendahl, P., Krattenmacher, N., Miglior, F., Weigel, K., Spurlock, D., Macdonald, K.A., Hulsegge, B. and R.F. Veerkamp. 2015. Genomic prediction of dry matter intake in dairy cattle from an international data set consisting of research herds in Europe, North America and Australasia. J. Dairy Sci. (in press).

Egger-Danner, C., P. Nielson, A. Fiedler, K. Müller, T. Fjeldaas, D. Döpfer, V. Daniels, C. Bergsten, G. Cramer, A.-M. Christen, K.F. Stock, G. Thomas, M. Holzhauer, A. Steiner, J. Clarke, N. Capion, N. Charfeddine, J. Pryce, E. Oakes, J. Burgstaller, B. Heringstad, B., C. Ødegård J. and J. Kofler. 2015. ICAR Claw Health Atlas. *www.icar.org/Documents/ICAR_Claw_Health_Atlas.pdf*.

EFSA. 2012. Scientific Opinion on the use of animal-based measures to assess welfare of dairy cows. EFSA Panel on Animal Health and Welfare (AHAW). EFSA Journal 2012; 10(1):2554.

Gernand, E., P. Rehbein, U.U. von Borstel and S. König. 2012. Incidences of and genetic parameters for mastitis, claw disorders, and common health traits recorded in dairy cattle contract herds. J. Dairy Sci. 95 (4): 2144-2156.

Giuliana, G.M.-P., Kaler J., Remnant J., Cheyne L., Abbott C., French A.P., Pridmore T.P. and J.N. Huxley. 2014. Behavioural changes in dairy cows with lameness in an automatic milking system. Applied Animal Behavioural Science 150, 1-8.

Green, L.E. Hedges, V.J. Schukken, Y.H. Blowey, R.W. and Packington, A.J. 2002. The impact of clinical lameness on the milk yield of dairy cows. Journal of Dairy Science. American Dairy Science Association,Savoy, USA: 2002. 85: 9, 2250-2256.

Häggman, J. and J. Juga. 2013. Genetic parameters for hoof disorders and feet and leg conformation traits in Finnish Holstein cows. J. Dairy Sci. 96, 3319-3325.

Hernández, J., J.K. Shearer and D.W. Webb. 2001. Effect of lameness on the calving to conception interval in dairy cows. JAVMA 218:1611-1614.

Johansson, K., Eriksson J.-Å., Nielsen, U.S., Pösö, J. and G.P. Aamand. 2011. Genetic evaluation of claw health in Denmark, Finland and Sweden. Interbull Bulletin 44, 224-228.

Koenig, S., A.R. Sharifi, H. Wentrot, D. Landmann, M. Else, and H. Simianer. 2005. Genetic parameters of claw and foot disorders estimated with logistic models. J. Dairy Sci. 88: 3316-25.

Koenig, S. and H.H. Swalve. 2006. Modelkalkulationen zu zuechterischen Moeglichkeiten auf Klauengesundheit beim Milchrind. Züchtungskunde 78, 345-356.

Kofler, J., Hangl, A., Pesenhofer, R., Landl, G. 2011. Evaluation of claw health in heifers in seven dairy farms using a digital claw trimming protocol and program for analysis of claw data. Berliner Muenchener Tierärztliche Wochenschrift 124, 10-19.

Kofler, J., Pesenhofer, R., Landl, G., Sommerfeld-Stur, I., Peham, C. 2013. Monitoring of dairy cow claw health status in 15 herds using the computerised documentation program Claw Manager and digital parameters. Tierärztliche Praxis 41 (G), 31-44.

Kofler, J., 2013. Computerised claw trimming database programs as the basis for monitoring hoof health in dairy herds. Veterinary Journal 198, 358-361.

Laursen, M.V., D. Boelling and T. Mark, 2009. Genetic parameters for claw and leg health, foot health and leg conformation, and locomotion in Danish Holstein. J. Dairy Sci. 92: 1770-1777.

Linde, C., de Jong G., Koenen D.P.C. and Eding H. 2010. Claw health index for Dutch dairy cattle based on claw trimming and conformation data. Journal Dairy Science 93, 4883-4891.

Meléndez, P., J. Bartolome, L., F. Archbald and A. Donovan. 2003. The association between lameness, ovarian cysts and fertility in lactating dairy cows. Theriogenology 59:927-937.

NAV Routine Evaluation. 2014. Nordic cattle genetic evaluation. *www.nordicebv.info*.

Nielsen, P. 2014. Claw health data - recording and usage in Denmark. ICAR-Treffen Berlin, Mai 2014. *www.icar.org/Documents/Berlin_2014/functional_traits_meeting.htm*.

Odegard, C., Svendsen, M. and B. Heringstad. 2013. Genetic analyses of claw health in Norwegian Red cows. J. Dairy Sci. 96: 7274-7283.

Rajala-Schultz, P. J. and Y. T. Gröhn, 1999. Culling of dairy cows. I. Prev. Vet. Med. 41: 195-208

Rouha-Mülleder, C., C. Iben, E. Wagner, G. Laaha, J. Troxler and S. Waiblinger. 2009. Relative importance of factors influencing the prevalence of lameness in Austrian cubicle loose housed dairy cows. PrevVetMed 92, 123-133.

Sogstad, A.M. 2014. Recording and reporting of claw lesions in Norway. ICAR-Treffen Berlin, May 2014.

Veerkamp, R.F., Beerda, B. and von der Lende, T. 2003. Effects of genetic selection for milk yield on energy balance, levels of hormones and metabolites in lactating cattle, and possible links to reduced fertility. Livest. Prod. Sci. 83: 257-265.

Van Pelt, M.L, 2015. Implementation of a claw health index in The Netherlands. Seminar des Ausschusses für Genetik der ZAR, Salzburg, 12. March 2015. *www.zar.at/Downloads/ZAR-Seminar.html*.

Stock, K.F., J. Cole, J. Pryce, J., N. Gengler, A. Bradley, L. Andrews and C. Egger-Danner. 2012. Survey on the recording and use of functional traits in dairy management and breeding. Proceedings ICAR Annual Meeting on 30 May 2012 in Cork, Ireland.

Thomas, G. and H. Leclerc. 2014. PARABOV and GénoPedix: Registration on hoof disorders in France. ICAR-Treffen Berlin, Mai 2014. *www.icar.org/Documents/Berlin_2014/functional_traits_meeting.htm*

Van der Waaij, E.H., M. Holzhauer, E. Ellen, C. Kamphuis and G. de Jong. 2005. Genetic parameters for claw disorders in Dutsch cattle and correlations with conformation traits. J. Dairy Sci. 88:3672-3578.

Warnick, L. D., D. Janssen, C. L. Guard and Y. T. Grohn. 2001. The effect of lameness on milk production in dairy cows. J. Dairy Sci. 84:1988-1997.

Whay, H. R., D. C. Main, L. E. Green and A. J. Webster. 2003. Assessment of the welfare of dairy cattle using animal-based measurements: Direct observations and investigation of farm records.Vet. Rec. 153:197?202.

Weber, A., E. Stamer, W. Junge, W. and G. Thaller. 2013. Genetic parameters for lameness and claw and leg diseases in dairy cows. J. Dairy Sci. 96: 3310-3318.