Animal Welfare 2009, 18: 433-439
ISSN 0962-7286

Cow gait scores and kinematic gait data: can people see gait irregularities?

A Van Nuffel*[†‡], M Sprenger[§], FAM Tuyttens[§] and W Maertens[‡]

[†] Burgemeesters Van Gansberghelaan 115 bus 1, B-9820 Merelbeke, Belgium
[‡] Agricultural Engineering, Technology and Food Unit, Institute for Agricultural and Fisheries Research, Merelbeke, Belgium
[§] Animal Husbandry and Welfare, Animal Sciences Unit, Institute for Agricultural and Fisheries Research, Melle, Belgium
* Contact for correspondence and requests for reprints: annelies.vannuffel@ilvo.vlaanderen.be

Abstract

Increasing lameness problems associated with intensified dairy cattle production has lead to the development of several techniques to automatically detect these problems. Comparisons of these new measuring techniques of cow locomotion with the conventional subjective observer scoring are scarce. In order to better understand human observers' gait scoring, cows walking on a pressure-sensitive mat were evaluated for kinematic gait variables and a visual assessment of gait was also made via video recording. Forty of these videos were used for subjective gait scoring on a 3-point scale, and the observers were also asked to report any observed abnormalities (lameness indicators) that had influenced their scoring. Relationships between reported lameness indicators and subjective gait scores, between subjective gait scores and measured kinematic variables of cow locomotion and between reported lameness indicators and measured kinematic variables of cow locomotion were investigated. In general, observers based their gait score on reported indicators such as 'tenderness', 'arched back', 'irregular gait' and 'increased abduction'. All of these four reported lameness indicators were correlated with measured kinematic 'variables of asymmetry', 'stance time' or both, suggesting that human observers are capable of detecting changes within these lameness indicators as measured by the pressure-sensitive mat. 'Increased abduction' appeared harder to detect and was reported more frequently by observers already experienced with gait scoring. Also, the measured kinematic variables of 'stance time' and 'measures of asymmetry between left and right limbs' as measured by the pressure-sensitive mat, show potential in predicting the gait score given. These reported lameness indicators and measured kinematic variables —mutually correlated and both related to the gait scores — were considered promising for subjective gait scoring in general.

Keywords: *animal welfare, automatic detection, dairy cows, gait score, kinematic gait data, lameness*

Introduction

One of the most prevalent problems in dairy production is lameness and this has been defined as an abnormal gait which is an attempt to minimise pain (Scott 1989). In cows, this may manifest itself in walking with reduced speed and taking short strides with one or more legs, as well as an arched back or lowering of the head. Various gait-scoring systems are available which differ in terms of the scale used (3- to 5-point scale) and in indicators of lameness. Well-known systems include those of Manson and Leaver (1988), Winckler and Willen (2001), and Sprecher *et al* (1997). However, all scoring systems share one common weakness: they are based on the ability of a human observer to detect, visually, the aforementioned lameness indicators and distinguish 'normal' from 'abnormal' walking behaviour. Even within a clearly-defined scoring system, visual lameness scoring, and human observation in general, remains inherently subjective. A consistency of 37 and 68% was found between observers by O'Callaghan *et al* (2003) and Winckler and Willen (2001), respectively, and, hence, observers need to be trained profoundly and repeatedly.

Objective gait analysis has been a topic of research for decades, but only recently have techniques for measuring spatial (Telezhenko & Bergsten 2005) and/or temporal variables (Flower *et al* 2005) of gait been adopted in cow lameness research. Other efforts have aimed to measure force or pressure-related variables (van der Tol *et al* 2005). For example, Tasch and Rajkondawar (2004) developed a walk-over force-plate detection system that records the hoof-ground reaction force and Pastell *et al* (2006) used the weight-bearing between hindlimbs in a milking robot. Maertens *et al* (2007) focused on the use of a pressure-sensitive mat to provide spatial, temporal and force-related variables.

Lameness detection systems for supporting daily herd health management should monitor changes in behaviour (eg walking) of individual cows on a specific farm, but for research purposes, comparing gait scores between herd groups is also of interest and all the techniques mentioned above can be of use. A device for lameness scoring as part of an on-farm welfare assessment, where no information on normal gait variables for individual cows exists, only seems conceivable if a clear relationship between measured

Figure 1

An example of the video material as presented to the observer panel. The cows are walking over a 6 m long, pressure-sensitive mat while being filmed from an oblique angle.

kinematic variable and subjective gait scoring can be established. Additionally, it is unclear the extent to which one or more very specific gait features, as measured in automated gait analysis (eg difference in stance time between all 4 hooves, differences in step length, etc), can be seen by human observers. For this reason, the ability of human observers to perceive irregularities measured by such systems should be investigated further.

Human perception of lameness is difficult to investigate. It is a comprehensive process whereby the observation of a variety of different gait or other, animal-related properties, leads to a generalised impression of the cow's lameness status. Some features (eg 'tracking up') are perceived as being more important than others, depending on the scoring system used and the human observer in question, and it is often unclear as to which indicators described in the scoring systems are the most easy to observe unambiguously. In this study, gait scoring was not used as a gold standard, but was investigated in relation to kinematic variables as measured by a pressure-sensitive mat. In order for a better understanding of human gait scoring, the following questions are investigated: (i) on which lameness indicators do observers base their gait scores; (ii) can observers detect lameness indicators as measured by the pressure-sensitive mat and (iii) what is the relationship between the given gait score and the kinematic variables as measured by an automated gait analysis system? To further this aim, an experiment was conducted with 40 participants of the 4th International Workshop on the Assessment of Animal Welfare at Farm and Group Level in Ghent, Belgium in September 2008, each scoring 40 videos of cows walking on a pressure-sensitive mat.

Materials and methods

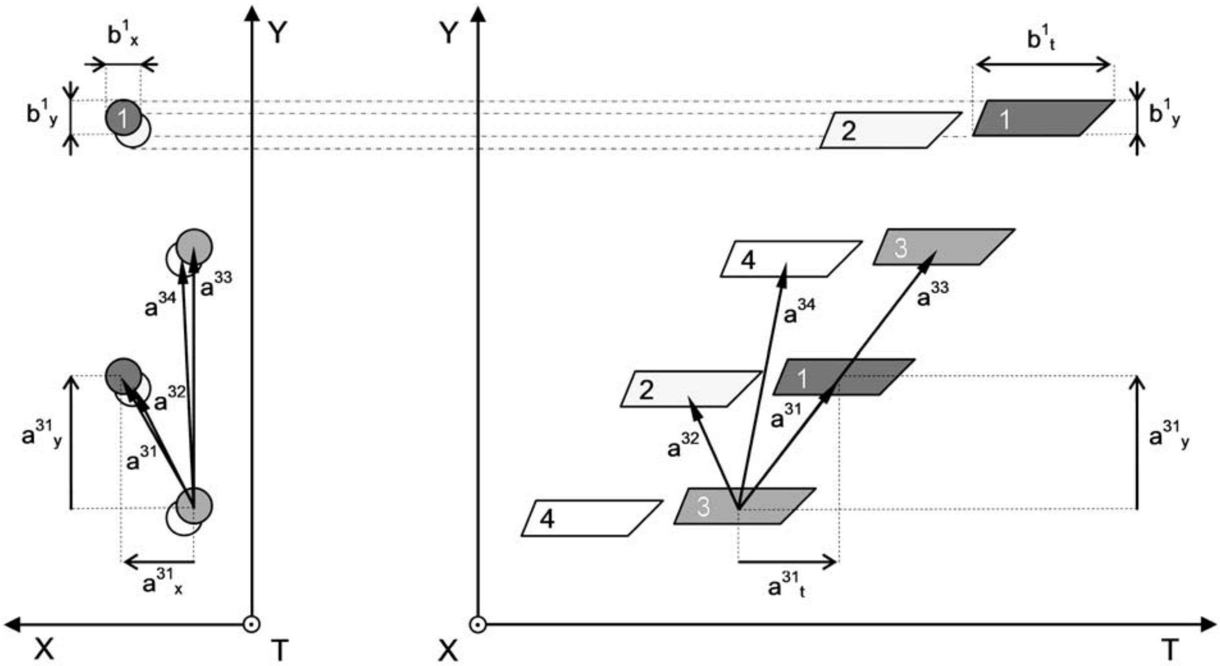
Measurement set-up

The data for this study were collected during the summer of 2008 during a two-hour workshop at the Animal Sciences Unit, Institute for Agricultural and Fisheries Research (ILVO, Ghent, Belgium). The gait of 80 lactating cows from a high-producing Holstein dairy herd were measured five days a week by a permanently-installed pressure-sensitive mat (Maertens *et al* 2008) in an outdoor retour alley of the milking parlour. A cow walking on the pressure-sensitive mat with a length of 6 m is shown in Figure 1. A Matlab® script (The Mathworks Inc, Natick, MA, USA) transforms raw data from the pressure-sensitive mat into spatial, temporal and force variables with respect to the hoof imprints over up to three consecutive gait cycles. As the pressure-sensitive mat was not force-calibrated, the force measures are values relative to the maximum pressure range of the sensors.

Simultaneously, the cows walking on the pressure-sensitive mat were filmed from an oblique angle (corresponding to the view in Figure 1) using a fixed camera (Canon A620, Canon Inc, Tokyo, Japan) at 30 frames per second with a 640 × 480 pixel resolution. Cows walked undisturbed as the individual performing the measurements was located indoors in a stable opposite the measurement location. Data from cows walking in an obviously irregular fashion eg, by accelerating, stopping and/or slipping and data from several cows walking simultaneously over the mat were excluded. During the summer of 2008, over 400 videos were scored by a skilled observer

https://doi.org/10.1017/S0962728600000841 Published online by Cambridge University Press

Figure 2



A schematic drawing of hoof imprints in 3D-space and some of the basic set of vectors describing the gait pattern. The XY-projection on the left shows hoof imprints without their temporal dimension (eg as hoof prints on the floor), and illustrates the spatial distribution of left hind hoof (LH), left front hoof (LF), right hind hoof (RH) and right front hoof (RF) imprints respectively. The YT-projection of the same 3D-diagram shown at the right side also shows the temporal aspects of hoof placement. Imprints of the LH, LF, RH and the RF hoof are labelled 1, 2, 3 and 4, respectively. Vectors labelled 'a' indicate between-hoof measures; vector 'b' points to within-hoof measures. The corresponding hoofs are written as superscripts and the dimension in which the measures are taken is subscripted.
a_x relates to the distance between hoof imprints along the X dimension, a_y relates to the distance between hoof imprints along the Y dimension and a_t relates to the distance between hoof imprints along the T dimension.

using a 3-point scale as mentioned below, in order to select 40 videos (further referred to as 'cases') representing cows with different gait scores (15, 20 and 5 cases with gait score 1, 2 and 3, respectively). Apart from ensuring that there were cases with differing degrees of irregularity in step symmetry and speed, this selection was random.

Gait scoring

At the start, the 40 participants were asked to record their name and their level of expertise in gait scoring from 1 (naïve) to 5 (expert). After a presentation of different lameness indicators used in conventional gait-scoring systems, a short training session based on eight videos using these indicators was held. Each case was shown four times, participants were asked to write down any observed lameness indicator and to give a gait score.

Half of the participants used a continuous score for the first 20 films and an ordinal score for the following 20 films, the other half used the ordinal scale first, followed by the continuous scale. For the ordinal score, participants were instructed to score '1' when a cow did not show any of the lameness indicators. Presence of one lameness indicator was scored '2'. A single lameness indicator showing a clear impediment in locomotion or the presence of multiple lameness indicators were scored '3'. Scoring on a continuous scale took the form of a mark being made on a 100-mm line showing both the number and severity of the detected 'lameness indicators.' (Tuyttens *et al* 2009). These scores were converted into the 3-point ordinal scale according to the continuous intervals (0%; 33%), (33%; 66%) and (66%; 100%) and merged with the set of ordinal scores. For each case and within different levels of observer experience, an average gait score, which is a continuous variable within the interval (1; 3), was used for further reference.

Kinematic gait data

From the set of kinematic variables (Maertens *et al* 2008) obtained from the pressure-sensitive mat and shown in Figure 2, a subset of kinematic variables relating to basic gait variables or relating to some symmetry aspects in gait was calculated (Table 1). The kinematic gait data was not normalised with respect to individual cow body conformation or size.

Table 1 Definitions of the calculated kinematic variables.

Kinematic variable*	Definition
AX (m)	$(\lvert a_x^{11}-a_x^{33}\rvert + \lvert a_x^{12}-a_x^{34}\rvert + \lvert a_x^{13}-a_x^{31}\rvert + \lvert a_x^{14}-a_x^{32}\rvert) \times 0.25$
AY (m)	$(\lvert a_y^{11}-a_y^{33}\rvert + \lvert a_y^{12}-a_y^{34}\rvert + \lvert a_y^{13}-a_y^{31}\rvert + \lvert a_y^{14}-a_y^{32}\rvert) \times 0.25$
AT (s)	$(\lvert a_t^{11}-a_t^{33}\rvert + \lvert a_t^{12}-a_t^{34}\rvert + \lvert a_t^{13}-a_t^{31}\rvert + \lvert a_t^{14}-a_t^{32}\rvert) \times 0.25$
AST (s)	$(\lvert b_t^{1}-b_t^{3}\rvert + \lvert b_t^{2}-b_t^{4}\rvert) \times 0.5$
AF (/)	$(\lvert b_f^{1}-b_f^{3}\rvert + \lvert b_f^{2}-b_f^{4}\rvert) \times 0.5$
Y (m)	$(a_y^{11} + a_y^{22} + a_y^{33} + a_y^{44}) \times 0.25$
T (m)	$(a_t^{11} + a_t^{22} + a_t^{33} + a_t^{44}) \times 0.25$
ST (s)	$(b_t^{1} + b_t^{2} + b_t^{3} + b_t^{4}) \times 0.25$
SO (m)	$(a_y^{21} + a_y^{43}) \times 0.5$
ABD (m)	$(\lvert a_x^{21}\rvert + \lvert a_x^{43}\rvert) \times 0.5$

* Kinematic variables of symmetry between left and right limbs in 'step width' (AX), 'step length' (AY), 'step time' (AT), 'stance time' (AST), 'relative force' (AF) and the basic kinematic variables 'stride length' (Y), 'stride time' (T), 'stance time' (ST), 'step overlap or tracking up' (SO) and 'abduction' (ABD). Variables a_x, a_y, a_t, b_x, b_y and b_t are explained in Figure 2.

Table 2 Mean gait score of the 40 cows for observers with different levels of expertise in gait scoring. Expert levels increase from 1 (naïve) to 4–5 (expert).

Expert level	Mean (± SD) gait score
1 (n = 718)	182 (± 0.68)[c,b]
2 (n = 279)	1.86 (± 0.67)[c]
3 (n = 280)	1.73 (± 0.67)[a,b]
4–5 (n = 280)	1.72 (± 0.68)[a]

[a, b, c] Homogeneous groups (Fisher Least Significant Distance, $P < 0.05$), n = total number of scores given for all cases within each expert level, dependant on the number of observers and the number of cases scored. Each observer scored each case only once.

The calculated kinematic variables cover asymmetry between left and right limbs in 'step width' (AX), 'step length' (AY), 'step time' (AT), 'stance time' (AST), 'relative force' (AF) as well as also covering basic variables describing 'stride length' (Y), 'stride time' (T), 'stance time' (ST), 'step overlap or tracking up' (SO) and 'abduction' (ABD). Numeric values were obtained using the definitions in Table 1. All asymmetry measures correspond to the degree of deviation from perfect symmetry between left limbs and right limbs.

Data processing and statistical analysis

Analysis of variance (one-way ANOVA) was used in an explorative sense in order to test for differences in gait scoring with regard to observer expert level. Expert levels were 1, 2, 3 and 4–5 (18, 7, 7, and 7 observers, respectively) and all 40 cases (videos) were included in the analysis (Table 2). Similar expert levels were grouped into expert level classes suggested by the results of a *post hoc* Fisher's Least Significant Distance test ($P < 0.05$). For all statistical analyses below, a class of observers familiar with gait scoring (expert level 3–5, n = 14) and a class of observers less familiar with gait scoring (expert level 1–2, n = 25) was used.

Differences between expert level class in reporting lameness indicators were quantified by counting the number of observers that marked the given lameness indicator as present. Frequencies of each reported lameness indicator relative to the number of familiar (14) or unfamiliar observers (25) were used as a comparison. For each lameness indicator, a Wilcoxon's pairwise comparisons test between lameness indicator frequencies of the familiar and unfamiliar observer class for each of the 40 cases was used (Table 3). One participant did not state his/her expert level and was left out of this part of the analysis.

To test which lameness indicators were contributing significantly to explaining gait scores, the mean gait scores that observers reported were analysed in relation to the relative frequency of different lameness indicators. These relative frequencies (as mentioned above) were used as independent variables for multiple linear regression with 'gait score' as a dependent variable (Table 4). To reduce the number of independent variables and control the interdependency of reported lameness indicators, irregular gaits of a 'spatial', 'temporal', 'spatio-temporal' or 'unspecified' nature, were pooled. The relative frequency of 'reduced tracking up' was left out of the analysis (no reported occurrences of this indicator within the unfamiliar observer group).

To explore the relationship between lameness behaviour observed and the measured kinematic variables, frequencies of reported indicator of lameness were compared with the kinematic variables, using Spearman rank correlations (Table 5).

Finally, to unveil the kinematics which were contributing to the gait scores, the mean gait scores were analysed with the measured kinematic gait variables in a second multiple linear regression procedure (see Table 6). To reduce the number of independent variables, each 'asymmetry' variable (AX, AY, AT, AST and AF) was re-scaled to a (0; 1) interval and the average value of these five asymmetry measures was defined as 'pooled asymmetry'. The 'stride time' variable was omitted from the set of dependent variables as it was highly correlated with 'stance time'.

The analyses were performed once for all observations and a second time for the unfamiliar and familiar observer class, separately. All statistical tests were performed using Statistica 8.0 (StatSoft Inc, Tulsa, OK, USA).

Results

Expert level was significant ($P = 0.02$) in explaining the variance of the gait scores. An overview of the mean gait scores for each expert level can be seen in Table 2.

'Reduced speed' and 'reduced tracking up' were rarely reported by the observers (Table 3). Unfamiliar observers did mention 'spatial irregularity' and 'irregular gait in space and time' indicators more than familiar observers. 'Increased abduction', 'arched back', 'temporal irregu-

Table 3 Reported frequency (relative to the number of observers) of different lameness indicators on 40 video cases, observed by observers familiar and unfamiliar with gait scoring.

Lameness indicator	Unfamiliar (n = 25)	Familiar (n = 14)	*P*-value
Tenderness	7.24*	6.50	0.12
Arched back	**4.88**	**7.29**	**< 0.001**
Reduced speed	**0.12**	**0.50**	**0.04**
Irregular gait unspecified	10.28	9.79	0.52
Irregular gait (spatial)	**4.28**	**2.64**	**0.01**
Irregular gait (temporal)	**4.72**	**6.93**	**0.002**
Irregular gait (both in space and time)	**1.40**	**0.64**	**0.002**
Reduced tracking up	0.00	0.21	0.11
Increased abduction	**0.12**	**2.21**	**< 0.001**
Head bobbing	0.84	0.86	0.76

P-values relate to Wilcoxon's pairwise comparison tests for each specific lameness indicator and covering all 40 cases; significant ($P < 0.05$) differences between familiar and unfamiliar observers are in bold.
* This value can be interpreted as: 'On average, tenderness was reported at 7.24 out of 40 cases, when considering the observers unfamiliar with gait scoring'.

Table 4 Standardised coefficients (β) and *P*-values after multiple linear regression analysis on different lameness indicator frequencies (as variables) and the average gait score (as dependent variable).

Lameness indicator	Regression characteristics within each observer group					
	All observers (R^2 = 0.93)		Unfamiliar (R^2 = 0.88)		Familiar (R^2 = 0.92)	
	P-value	β	*P*-value	β	*P*-value	β
Tenderness	**< 0.001**	**0.36**	**< 0.001**	**0.46**	**< 0.001**	**0.31**
Arched back	**< 0.001**	**0.32**	**< 0.001**	**0.27**	**< 0.001**	**0.28**
Reduced speed	0.41	–0.04	0.13	–0.09	0.14	0.09
Irregular gait	**< 0.001**	**0.45**	**< 0.001**	**0.52**	**< 0.001**	**0.38**
Increased abduction	**0.004**	**0.18**	**0.003**	**0.19**	**0.005**	**0.18**
Head bobbing	0.52	0.03	0.22	0.07	0.87	–0.01

Variables that significantly ($P < 0.05$) influence the gait score in this class of observer expertise are shown in bold.

larity' and 'reduced speed' were more frequently used by the familiar observers.

As shown in Table 4, the gait score was partially explained by the reported lameness indicators 'tenderness', 'arched back', 'irregular gait' and 'increased abduction'.

Spearman rank correlations are shown in Table 5 and give detailed information on the relationship between the relative frequency of each reported lameness indicator and the measured kinematic variables. When considering reported lameness indicators counted over all observer expert levels (as in Table 5), 22 pairs (reported vs measured variables) are significant. When considering expert level classes separately, this dropped to 13 and 17 significant correlations for unfamiliar and familiar observers, respectively. No significant correlation between reported 'head bobbing' or 'reduced tracking up' and any of the measured kinematic variables was found. Observed 'tenderness' showed a high correlation with ($r > 0.5$) with 'stride and stance times'. Other expected significant correlations are shown in Table 5.

For all expert levels, the kinematic variable 'stance time' contributed most in predicting the gait scores given (Table 6). 'Pooled asymmetry' also contributed significantly within the unfamiliar observer group.

Discussion

In general, expert gait scores (level 4–5) were lower than those of the unfamiliar observer class (level 1–2). No cases of severely lame cows were used, and as the more experienced observers are more familiar with very lame cows, it is possible that they used a higher threshold to gait score the cows in these video cases. Observers unfamiliar with gait scoring mention 'spatial irregularity' and 'irregularity in space and time' more often than those more familiar. In contrast, the indicators 'increased abduction', 'arched back', 'reduced speed' and 'temporal irregularity' were

Table 5 Significant ($P < 0.05$) Spearman rank correlation coefficients between the frequency of a specific lameness indicator (rows) and the measured kinematic variable (columns). All observer levels were taken into account.

Lameness indicator	Kinematic variable[1]									
	AX	AY	AT	AST	AF	Y	T	ST	SO	ABD
Tenderness	0.48*	–	–	–	a	–	0.76**	0.77**	–32	0.41
Arched back	–	–	–	–	–	–	0.45*	0.51**	–	–
Reduced speed	–	–	–	–	–	–0.39[b]	0.40[b]	0.41	–	–
Irregular gait (unspecified)	[a]	0.40[b]	–	–	–	–	0.49*	0.50*	–	–
Irregular gait (spatial)	[a]	0.34[b]	–	–	–	–	–	–	–	–
Irregular gait (temporal)	–	0.43*	[a]	[a]	0.45*	–	–	–	–	–
Irregular gait (spatial and temporal)	[a]	[a]	[a]	[a]	0.33	–	–	–	–	–
Reduced tracking up	–	–	–	–	–	–	–	–	[a]	–
Increased abduction	0.47*	–	–	–	–	–	0.41*	0.45*	–0.37	0.33b
Head bobbing	–	–	–	–	–	–	–	–	–	–

[1] Kinematic variables: Variables of symmetry between left and right limbs in: 'step width' (AX), 'step length' (AY), 'step time' (AT), 'stance time' (AST), 'relative force' (AF) and basic kinematic variables: 'stride length' (Y), 'stride time' (T), 'stance time' (ST), 'step overlap or tracking up' (SO) and 'abduction' (ABD).
[a, b] Expected agreement between (related) observed and measured variables which were either significantly (b) or not significantly correlated (a). Correlations that were not significant are shown as –.

Table 6 Standardised coefficients (β) and *P*-values after multiple linear regression analysis on a subset of measured kinematic variables and the average gait score (as dependent variable).

Kinematic variable	Regression characteristics within each observer group					
	All observers ($R^2 = 0.53$)		Unfamiliar ($R^2 = 0.53$)		Familiar ($R^2 = 0.45$)	
	P-value	β	*P*-value	β	*P*-value	β
Pooled asymmetry*	0.06	0.24	**0.03**	**0.27**	0.20	0.17
Stride length (Y)	0.53	0.08	0.55	0.08	0.57	0.08
Stance time (ST)	**< 0.001**	**0.54**	**< 0.001**	**0.52**	**0.001**	**0.53**
Step overlap (SO)	0.14	–0.19	0.19	–0.17	0.14	–0.21
Step abduction (ABD)	0.11	0.18	0.10	0.20	0.21	0.16

Variables that play a significant role in explaining the gait score in this class of observer expertise are shown in bold ($P < 0.05$).
* The 'pooled asymmetry variable' was calculated by taking the average of five asymmetry variables after normalisation. These asymmetry variables relate to the difference (left to right) in 'step width' (AX), 'step length' (AY), 'step time' (AT), 'stance time' (AST) and 'relative force' (AF).

mentioned less. The popularity of the Sprecher gait-scoring system might explain the focus on 'arched back' by the observers familiar with that gait scoring system (Sprecher *et al* 1997). Furthermore, 'abduction' and 'temporal irregularity', which are more difficult concepts, are likely to be used more frequently by experienced observers. The lack of reported 'reduced tracking up', also known as 'step overlap' is remarkable, and 'increased abduction' might have been confused with this. 'Irregular gait' seems to have been a slightly difficult indicator to address consistently, and was mostly found correlated with 'asymmetry in step length', possibly due to the cows being filmed from aside. Reported 'temporal asymmetry' was correlated with measured 'relative force asymmetry' but, surprisingly, it was not correlated with 'asymmetry in time' as measured by the mat. This indicates that 'asymmetry in time' is difficult to observe unambiguously but that it has some potential to assess the 'reluctance to bear weight' as mentioned in, eg Winckler *et al* (2001). Reported 'tracking up' was not correlated with the measured 'step overlap or tracking up'. This can be explained by the fact that tracking up was mentioned only three times for all video cases and all observers. As expected, reported 'increased abduction' was correlated with measured 'increased abduction' but is used predominantly by experienced observers. As such, this seems to be a valuable lameness indicator, but one which needs a degree of training before being used by human observers.

As mentioned in a number of cases above, there was not always a clear correlation between the lameness indicator reported by the observer and the kinematic indicators as measured by the pressure-sensitive mat. Contrary to reported 'asymmetry in time', an expected correlation between the frequently reported 'tenderness' and measured 'asymmetry in relative force' was seen. Also, the multiple correlations with other frequently-used indicators may mirror the absence of a clear definition of 'tenderness'. Both 'arched back' and 'head bobs' could not be measured directly by kinematic gait variables as only the claws made contact with the pressure-sensitive mat. However, 'arched back' was correlated with the kinematic parameters 'stride time' and 'stance time', which suggests that cows that walked slowly (high stance and stride time) had arched backs. No correlations were found between 'head bobs' and any of the kinematic variables. Reported 'irregular gait in time and space' and 'reduced speed' are among the primary indicators reported by observers. Moreover, both of these reported lameness indicators were correlated with corresponding measured kinematic variables, suggesting that they were truly present and relevant when trying to better understand human observer scoring behaviour.

A model to predict gait scores based on kinematic gait measures requires an understanding of the human perception of lameness. The presented way of analysing the gait scoring behaviour of observers based on video footage and matching kinematic variables of the pressure-sensitive mat with reported lameness indicators, provides an insight into a better understanding of human gait-scoring behaviour but has certain drawbacks. In this study, no conclusions could be drawn regarding the threshold upon which a human observer notices the onset of lameness via one or multiple subtle changes in lameness indicators. This would require a large amount of slightly different recordings. Furthermore, observers could be biased by factors such as viewing angle, cows' cleanliness or body condition and even cow colour or auditory clues. Ideally, video footage and kinematic gait data from cows that evolve from sound to very lame, using one specific indicator to show their lame behaviour, should be collected. Only if all other parameters are controlled for, can the threshold from sound to lame scoring for that specific indicator be investigated and animated 3D-computer graphics (Westhoff & Troje 2007 or http://www.biomotionlab.ca/Demos/BMLwalker.html) may make this approach feasible.

A first step towards estimating the usefulness of the kinematic variables in gait scoring has been taken by comparing kinematic variables to gait scores as a reference: 'stance time' (or correlated 'stride time') and 'variables of asymmetry' contributed significantly to predicting gait scoring given by observers. Validation of the objective measurement system is not the goal of this study, but when the system is used during a single animal welfare assessment, these kinematic variables of 'stance time' or 'asymmetry between left and right limbs' seem promising. Gait scoring itself appeared to be related to reported lameness indicators such as 'tenderness', 'arched back', 'irregular gait' and 'increased abduction', which were correlated to measured kinematic variables of 'asymmetry between left and right limbs' and 'stance time' or 'stride time'. This suggests that these lameness indicators and kinematic variables are relevant for gait scoring.

Animal welfare implications

Understanding the process of gait scoring is essential for the development of a reliable gait-scoring system. The present findings help in the understanding of this process. Reliable gait scoring is essential for improvement of cow health and welfare.

Acknowledgements

This project is funded by IWT-Vlaanderen (Institute for the Promotion of Innovation through Science and Technology in Flanders). Thanks are due to all participants of the lameness workshop during WAFL and the experts of the lameness workshop held in December 2007 (ILVO, Ghent-Belgium), our technical staff for their help with the experimental set-up and to the people of the ILVO Research Farm for taking care of the animals.

References

Flower FC, Sanderson DJ and Weary DM 2005 Hoof pathologies influence kinematic measures of dairy cow gait. *Journal of Dairy Science 88*: 3166-3173

Maertens W, Baert J, Vangeyte J, Vranken E, Berckmans D and Sonck B 2007 Acquisition techniques for dairy cow gait analysis. *Proceedings of the Third European Conference on Precision Livestock Farming*. 3-6 June 2007, Skiathos, Greece

Maertens W, Opsomer G, Van Dongen S, Song X, De Campeneere S, Bahr C, Van Nuffel A, Baert J, Vangeyte J, Berckmans D and Sonck B 2008 Measurement of cow locomotion on a large pressure sensitive walkway. *Proceedings of the 15th Symposium and 7th Conference on Lameness in Ruminants*. 9-13 June 2008, Kuopio, Finland

Manson FJ and Leaver JD 1988 The influence of concentrate amount on locomotion and clinical lameness in dairy cattle. *Animal Production 47*: 185-190

O'Callaghan KAO, Cripps PJ, Downham DY and Murray RD 2003 Subjective and objective assessment of pain and discomfort due to lameness in dairy cattle. *Animal Welfare 12:* 605-610

Pastell M, Aisla AM, Hautala M, Poikalainen V, Praks J, Veermae I and Ahokas J 2006 Contactless measurement of cow behaviour in a milking robot. *Behavior Research Methods 38*: 479-483

Scott GB 1989 Changes in limb loading with lameness for a number of Friesian cattle. *British Veterinary Journal 145*: 28-38

Sprecher DJ, Hostetler DE and Kaneene JB 1997 A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. *Theriogenology 47*: 1179-1187

Tasch U and Rajkondawar PG 2004 The development of a SoftSeparator for a lameness diagnostic system. *Computers and Electronics in Agriculture 44*: 239-245

Telezhenko E and Bergsten C 2005 Influence of floor type on the locomotion of dairy cows. *Applied Animal Behaviour Science 93*: 183-197

Tuyttens FAM, Sprenger M, Van Nuffel A, Maertens W and Van Dongen S 2009 Reliability of categorical versus continuous scoring of welfare indicators: lameness in cows as a case study. *Animal Welfare 18*: 399-405

Van der Tol PPJ, Metz JHM, Noordhuizen-Stassen EN, Back W, Braam CR and Weijs WA 2005 Frictional forces for unrestrained locomotion in dairy cattle. *American Dairy Science Association 88*: 615-624

Westhoff C and Troje NF 2007 Kinematic cues for person identification from biological motion. *Perception & Psychophysics 69*: 241-253

Winckler C and Willen S 2001 The reliability and repeatability of a lameness scoring system for use as an indicator of welfare in dairy cattle. *Acta Agriculturae Scandinavica: Section A, Animal Science 30*: 103-107