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Automatically measured variables related to tenderness of hoof placement and weight distribution are valuable indicators for lameness in dairy cows

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ABSTRACT

As lameness detection in dairy cattle using visual locomotion scoring is cumbersome and subjective, research efforts are dedicated to develop automatic lameness detection systems. 'Tender hoof placement' and the distribution of the body weight over the four legs are possible lameness indicators, but no research exists on how to derive from automatically measured gait characteristics. This study aims to derive new variables related to the (i) landing, full weight bearing and lifting phases of a stance time and the (ii) time spent on combinations of legs during the different phases of the gait cycle from cow gait recordings on a dedicated pressure mat, known as the Gaitwise. Data of 9 non-lame, 11 mildly lame and 12 severely lame cows were gathered. For all measurements, each variable was calculated per leg or combination of legs, after which the group means of each variable were compared between the three lameness statuses using a one-way ANOVA analysis. Landing and lifting variables indicated that the proportion of time for hoof placement and hoof lifting during the total stance time was longer in lame cows, and that the proportion of full weight bearing time was shorter. Lame cows were thus more careful to place and retract the hind feet in the case of a hind-lame leg. Support time variables indicated that lame cows increased the percentage triple support time (i.e time spent with three feet on the ground during walking) and lowered the percentage double support (i.e. time spent with two legs on the ground). Also, double support combinations on the same side of the body were preferred above diagonal combinations. The newly defined gait variables indeed reflect tenderness of hoof placement and body weight distribution and hence seem useful for discriminating between non-lame, mildly lame and severely lame cows. However, several of these interesting variables may have to be combined to obtain automatic lameness detection with sufficient accuracy.

1. Introduction

Lameness is recognized as one of the main health and welfare challenges on modern dairy farms. As farms are getting larger (Bewley et al., 2001), the time consuming monitoring of individual cows becomes even more difficult. Therefore, technologies are being developed to support the farmers by automatically detecting lameness (Munksgaard et al., 2006; Flower et al., 2005; Neveux et al., 2006; Pastell et al., 2009; Chapinal et al., 2011; Maertens et al., 2011; Skjoth et al., 2013; Van Hertem et al., 2014). Such systems rely on measuring cow gait characteristics that are different between lame and non-lame cows and algorithms that can detect these changes. The gait characteristics measured by these technologies are generally based on lameness indicators used during visual locomotion scoring.

Visual lameness indicators have been shown to be closely related to lameness. However, they often tend to be clearly visible in severely lame cows, but less obvious in mildly lame cows.

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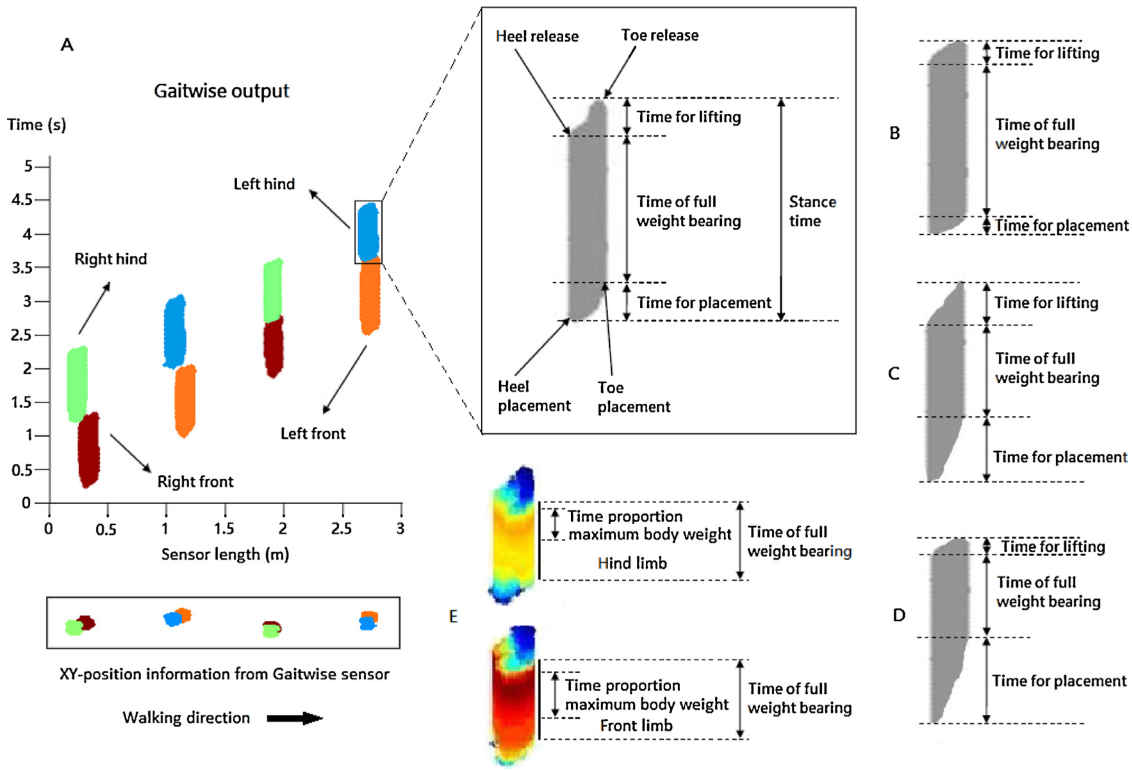

Fig. 1. Schematic representation of the new variables 'time for hoof placement' (landing), 'time for full weight bearing' (duty) and 'time for hoof release' (lifting). The XY and YT representation of the Gaitwise output are shown on the left. Each leg is indicated by a specific color: left hind (blue), right hind (green), left front (orange) and right front (red). The YT representation of a left hind imprint is shown in figures A–E. (A) normal stance time and deducted variables; (B–D) abnormal partition between the three timeframes of the stance time; (E) Visual representation of the proportion of the mid-stance phase where the force reaches its maximum value for that imprint relative to the entire mid-stance phase (maximum pressure: level 7, red; minimum pressure: level 0, blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

On the other hand, the indicator 'tenderness of hoof placement' or 'tenderness' was observed much more in mildly lame cows during visual locomotion scoring compared to the other indicators. There is, however, no proper definition available for 'tenderness of hoof placement' (Van Nuffel et al., 2015b), nor has this lameness indicator ever been thoroughly investigated using technology-derived variables that quantify how the hoof is placed on the ground. Similarly, shifts in double and triple support time, describing the time walking cows spend with two or three feet on the ground respectively, have been suggested as valuable indicators (Flower et al., 2005). However, they have never been used in visual locomotion assessment, as human observers are not able to see and hence score such gait characteristic due to the small time intervals and the subtleness of the changes herein.

To investigate the possible added value for lameness detection of variables describing the way the full body weight is supported by the four legs during a complete gait cycle research, several new variables were defined using the Gaitwise data. In this study, these variables were evaluated for their usefulness to distinguish between non-lame, mildly lame and severely lame cows.

2. Materials and methods

2.1. Background

In Table 1, indicators that are frequently used in visual locomotion scoring systems are listed together with technologies that can directly or indirectly measure such indicators. As mentioned before, no technology has been used to measure the indicator 'tenderness of hoof placement'. However, pressure plates, pressure mats or camera systems may be able to measure tenderness of hoof placement.

To better understand the usefulness of these suggested variables that describe how a cow supports her body weight between her four legs, the gait and hoof placement of cows need to be closely monitored. Maertens et al. (2011) developed a pressure mat, known as the Gaitwise, to monitor the contact between the hoof and the ground at a high frequency (60 Hz). This technology could provide a better insight in the events taking place during the transition of the hoof from a non-weight bearing to a full weight bearing position and vice-versa within one leg as well as the redistribution of the full body weight over the four legs.

2.1.1. Hoof placement

In Fig. 1, the gait data acquired using the Gaitwise system for a cow is visualized in detail. On the left, the XY and YT representations of the Gaitwise output are shown for a cow walk from left to right. The XY representation shows the imprints of the hooves on the floor from a top view. The YT representation shows the imprints in the walking direction and the time of the walk. The stance time of each imprint can be derived by subtracting the time of the first contact of the hoof with the ground from the time of the last contact with the ground. Each leg is indicated by a specific color. In Fig. 1A–D the YT dimensions of an imprint of one single hoof are illustrated. As demonstrated in Fig. 1A, the total stance time of an imprint can be divided into three phases: (1) a landing phase in which the hoof is placed on the ground, starting from the first contact of the heel until the whole hoof rests on the ground, (2) a full weight bearing phase in which the whole hoof is on the ground and the weight of the cow is supported, and (3) a lifting phase where the hoof is