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Variables of gait inconsistency outperform basic gait variables in detecting mildly lame cows

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ABSTRACT

To support herdsmen in finding the lame cows on their herds, several automated systems that measure lameness related cow features such as gait patterns, are being developed. Most of these systems are able to distinguish between non-lame and severely lame cows. Detecting mildly lame cows in an early stage of lameness however seems challenging. Inspired by the approach used in human gait research, new variables that measure the inconsistency in stride-to-stride variables were tested using cow gait and were able to show differences between a group of non-lame and a group of mildly lame cows. In order to investigate the added value of these inconsistency variables in detecting mildly lame cows, two new lameness detection models were build: one using solely basic gait variables and a second model using both basic and the new gait inconsistency variables. The second model using the gait inconsistency variables outperformed the model based on only basic gait variables by far in detecting the mildly lame cows with a sensitivity of 88% and a specificity of 87%. These results support the suggestion of incorporating such gait inconsistency variables into lameness detection models. Further validation of these gait inconsistency variables should be investigated using longitudinal studies where cows developing lameness and recovering from it are monitored daily.

1. Introduction

Due to the increasing numbers of cows per farm and hence per herdsman, the time to properly inspect every individual cow in their herd decreases. Therefore, sensors are being used to support the herdsmen to monitor their cows by automatically assessing cow specific features such as somatic cell count for mastitis or activity for estrus detection. Besides mastitis and fertility problems, the high prevalence of lame cows on dairy herds is one of the main challenges the dairy industry is currently facing (Huxley et al., 2013). To apply effective treatment and ailment prevention, herdsmen must

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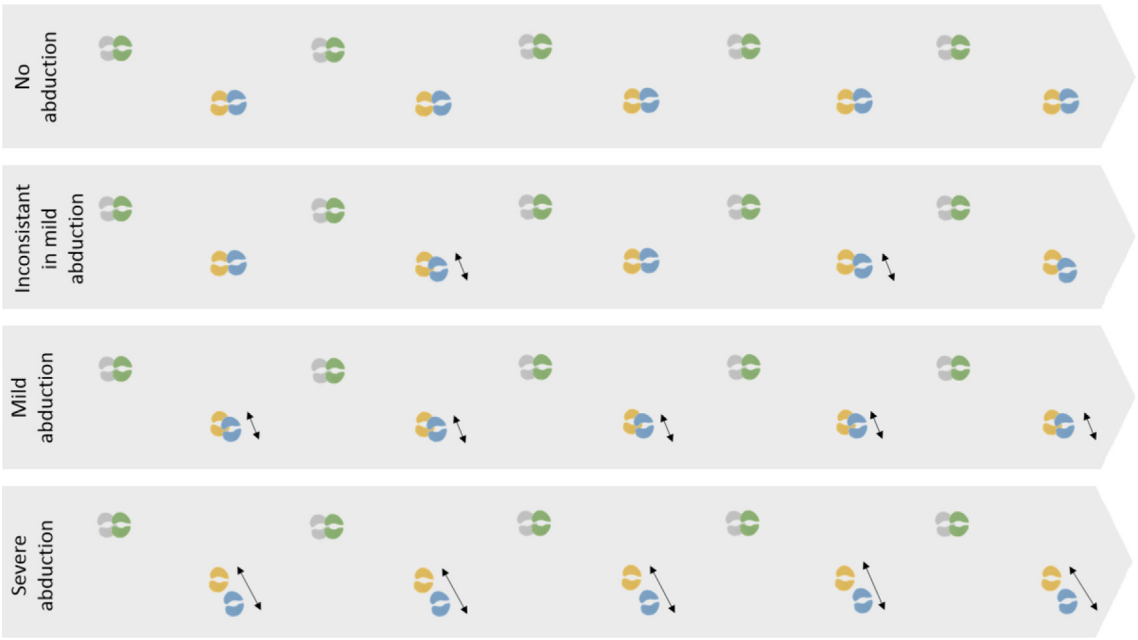

Fig. 1. Visualization of the gait inconsistency hypothesis for early lameness detection: before non-lame cows show mildly or severe abduction during the development of lameness, they first show stride-to-stride fluctuations or 'inconsistency' in showing the mild abduction.

be able to detect the lame cows in their herd in an early stage in order to prevent the cause of the lameness from developing into a chronic situation (Clarkson et al., 1996; Zimmerman, 2001). When lame cows are treated within two weeks of becoming lame, recovery rates can be 60–75% higher than when treated under conventional treatment protocol (Leach et al., 2012). As a result early lameness detection could reduce the costs of treatment and milk losses thanks to the more effective treatment (Gonzàlez et al., 2008).

For several years, lameness research in cattle has been focused on quantitative and automatic methods to analyze gait as an alternative for the more subjective and time consuming visual locomotion scoring methods. One of these approaches is the development of Gaitwise, a walk-over device with an integrated pressure sensitive mat and specific software that calculates spatial (e.g. step length), temporal (e.g. stance time) and force related gait variables of claw–floor interactions of cows walking over the measurement zone (Maertens et al., 2011). Assuming that these gait variables change when a cow develops lameness, Gaitwise could serve as a lameness detection system that alerts the farmer of cows that show changes in these variables that are related to lameness. Gaitwise provides fully automated measurements of gait variables that are available in real time. To describe the spatial (forward and sideward) and temporal relation between the different imprints of the four different legs of the cow during walking, 20 basic gait variables were analyzed as described in Maertens et al. (2011). These basic gait variables (e.g. step width between imprint of the left front leg and the imprint of the right hind leg) are ideal to describe the general gait of the cows. In addition, 10 more specific gait variables were calculated in order to quantify different lameness attributes that are often used in visual locomotion scoring systems which were calculated using the averaged value (of the two gait cycles measured during one measurement on the Gaitwise) of a combination of several basic gait variables. These 10 specific gait variables are: Stride length (*Y*), stride time (*T*), stance time (*ST*), step overlap (*SO*), abduction (*ABD*), and asymmetry between left and right limbs in step width (*AX*), step length (*AY*), in step time (*AT*), in stance time (*AST*) and in force (*AF*) and the definitions are described in Maertens et al. (2011). The detection algorithm of Maertens et al. (2011) was solely based on these 10 specific gait variables to correctly classify non-lame, mildly lame and severely lame cows with a sensitivity of 85%, 76%, 90% and specificity of 86%, 89%, and 100%, respectively. These results revealed that the combination of the specific gait variables used in this model ('stride length', 'stride time', 'step overlap', 'abduction' and asymmetry between left and right limbs in stepwidth', 'asymmetry in steplength', 'asymmetry in step-time', 'asymmetry in stance time' and 'asymmetry in relative force'), was efficient in distinguishing between non-lame and severely lame cows but detecting mildly lame cows was more challenging as the differences with non-lame cows are much smaller. These results were also found in Van Hertem et al. (2014).

However, the added value of lameness detection systems would increase considerably when also the mildly lame cows could be detected. To improve the detection of mildly lame cases, the potential of gait inconsistency variables for detecting lameness in such early stages was explored by Van Nuffel et al. (2013). This approach is based on the fact that in human gait research, increased stride-to-stride fluctuations (i.e. gait inconsistency) were found to be more closely related to early health problems compared to average gait variables (Hausdorff, 2005). The potential of gait inconsistency variables for early lameness detection was elaborated in cows by investigating whether a cow that