Technical note: Validation of an automatic recording system to assess behavioural activity level in sheep (*Ovis aries*).

Highlights

Actiwatch Mini® can distinguish between high and low activity behaviour in sheep.

The Actiwatch Mini® provides a tool to automatically monitor behavioural changes.

Detection of decreased activity levels due to disease can improve animal welfare.

Technical note: Validation of an automatic recording system to assess behavioural activity level in sheep (*Ovis aries*).

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Abstract

The welfare of an individual can be assessed by monitoring behavioural changes, such as inactivity, that may indicate injury or disease. In this study we validated the Actiwatch Mini® activity monitor (AM) for automatic recording of behavioural activity levels of nine Texel ewes. The AM devices were attached to collars placed around the necks of the ewes. AM recordings were taken at 25 second intervals for 21 consecutive days and in addition, direct behavioural observations made on days 9 to 13. AM recordings were compared with direct behavioural observations to investigate whether different levels of behaviour activity could be distinguished by the AM. Six different behaviours were matched to the activity scores recorded by the AM which were low activity (lying ruminating, lying), medium activity (standing, standing ruminating, and grazing) and high activity behaviours (walking). There were differences in the activity scores for all three scores. However, higher levels of accuracy in distinguishing between activity levels were achieved when combining high and medium activity level behaviours. This method of capturing data provides a practical tool in studies assessing the impact of disease or injury. For example, assessing the effects of lameness on the activity level of sheep at pasture, without the presence of an observer influencing behaviour.

Key words

Sheep; Behaviour; Validation; Welfare; Activity monitor.

1. Introduction

Monitoring behavioural changes in farm animals can improve welfare by providing information on an individual's health (Müller and Schrader, 2003). Progressive changes in activity levels can be a useful diagnostic sign of injury or disease onset (Gougoulis et al., 2010). A decrease from normal activity may indicate the need to avoid stimulating damaged tissue (Rutherford, 2002). Earlier detection of disease can lead to prompt and thus more effective treatment. If an individual's low activity level or inactivity is not detected for an extended length of time, the adverse effect on welfare will be prolonged (Broom, 2008) and there may be more impact upon productivity (Winter, 2008). Close monitoring of animals maintained at pasture is time consuming and labour intensive, and the presence of an observer can disrupt normal behaviour patterns (Nielsen, 2013). Automatic recording of behaviour would be a useful management tool for animals at pasture.

Several automatic recording devices are available for monitoring activity levels in farm animals; IceTag® activity monitors

(Mattachini et al., 2013; McGowan et al., 2007), HOBO® Pendant G Data Logger (Nielsen, 2013) and Tinytag® data loggers (O'Driscoll et al., 2008) have all been used to monitor cattle behaviour. These systems provide a reliable objective measure of behavioural activity, showing a high correlation between direct behavioural observations and the data from the device (Trénel et al., 2009). Automatic recording devices can capture daily activity patterns of several animals over long periods. They have provided valuable information on grazing, lying and standing behaviour of dairy cattle at pasture (Nielsen, 2013; O'Driscoll et al., 2008), and the occurrence of oestrus in dairy cattle (McGowan et al., 2007). Umstätter et al. (2008) showed that such devices could be used to monitor behaviour whilst animals are maintained extensively at pasture without the need for an observer.

The Actiwatch Mini® (CamNtech, Cambridge, UK) is an ultra light-weight, collar mounted device designed for use in animals. It has previously been used in sheep for studying the effects of feeding regimes and housing systems on circadian rhythm (Piccione et al., 2011, 2007) and for monitoring the general activity pattern of sheep with Huntington's disease (Morton et al., 2014). The aim of the present study was to validate the Actiwatch Mini® automatic recording device for measuring behavioural activity levels in sheep at pasture by comparing the output with observed behaviour.

2. Methods

2.1 Animals and living conditions

Ten multiparous Texel ewes (mean age 7 years ± 0.49) in a group of 46 cull ewes were selected for use in the study. All ewes were kept extensively at grass with unrestricted access to water and fed concentrate feed once a day at 08:00 h. Animals were gathered at the beginning and end of the study to attach and remove the devices.

2.2 The Actiwatch Mini® (AM)

The AM was encased in a small, waterproof box (350mm x 200mm x 350mm) and attached to a standard collar fitted around the neck as described by Piccione et al. (2011, 2007). All sheep accepted the collar without apparent disturbance. The AM was set to record and store data at 25 second epochs for 21 days. The AM device contains an omnidirectional accelerometer to monitor the occurrence and intensity of movement producing an activity count. Data were uploaded at the end of the study to ClockLab (Actimetrics, Wilmette, IL, USA). To ensure safety and good welfare, twice daily checks on the ewes were carried out by the farmer.

2.3 Direct behavioural observations

Behavioural observations were made for five consecutive days (days 9-13) from a hide and recorded by instantaneous scan-sampling at 1 min intervals for 20 minutes between 10:00 h and 15:00 h in a random order. Scans of 1 minute intervals were chosen to ensure collection of sufficient data from all sheep within the time period. Intervals of short duration (<2 minutes) have been demonstrated to be accurate and precise for measuring the daily amount of time spent laying and standing in dairy cattle (Mattachini et al., 2013; Müller and Schrader, 2003). Ewes were marked using stock spray for visual identification. The behaviour of each ewe was recorded as soon as they were identified when the field was scanned from right to left. Ewes remained within the same field throughout the observation period. Ewes were observed at least once a day with 9 scans per animal over the total observation period. Each animal's behaviour was categorised according to the list in table 1, and recorded manually on each occasion.

2.4 Ethical note

Ethical approval was provided by the Department of Veterinary Medicine, University of Cambridge Ethics and Welfare Committee. Every effort was made to ensure that sheep were not disturbed during data collection. All ewes were under the care of a veterinarian and monitored for signs of lameness or disease at the beginning and end of the study. One ewe within the study group was noted to have become lame and was treated for this by a veterinarian. No other signs of disease or lameness were noted.

3. Statistical analysis

One animal was removed from the analysis due to becoming lame during the study. Behavioural observations were matched to the activity recordings from the AM in order to validate the ability of the AM to detect different activity levels. Timings of the behavioural observations were matched to the appropriate time on the AM recordings. For each minute of behavioural observation, a sum of the activity counts for each 25 seconds recorded on the AM for the same minute was calculated (see figure 1). Activity scores calculated for each behaviour were compared using a one-way ANOVA. Mean activity scores for each behaviour were then calculated and a range determined for 'high', 'medium' or 'low' activity behaviour using the mean ± 1

SD. To calculate thresholds for each activity level and to ensure there was no overlap the midpoint between each of the ranges (mean ± SD) was determined. Accuracy of each of the categories was determined by calculating how many values from each range fell into an incorrect category. All statistical analyses were performed using Prism 5 (GraphPad Software Inc., San Diego, USA).

4. Results

The mean and standard error of activity scores for each of the six behaviours recorded on the AM is shown in figure 2. There was an overall difference in the activity scores of individual behaviours $F_{(5,1185)} = 87.61$, $p < 0.0001$. Post-hoc tests revealed differences between the activity scores of walking, categorised as ‘high’ activity and grazing/standing behaviours categorised as ‘medium’ activity ($p < 0.05$), differences between medium activity (grazing and standing) behaviours and low activity (lying) behaviours ($p < 0.05$) and differences in walking and lying behaviours ($p < 0.001$). There were no differences between grazing and the two standing behaviours, no difference between the two lying behaviours and no difference between the two standing behaviours.

The calculated thresholds are displayed in figure 3 for each of the high, medium and low activity levels. The overall accuracy levels were 59.09%, 3.37% and 74.56% for high, medium and low activity behaviours respectively. The low level of accuracy for the medium activity was due to 65.5% and 31.12% of medium activity behaviours falling into the low and high activity thresholds respectively. For practical purposes, having an ability to distinguish between 'active' and 'inactive' states is necessary. When medium activity behaviours were combined with walking to make an active category (see figure 4) a higher overall accuracy was achieved; 79.98% and 74.56% for active and inactive respectively. This also reduced the amount of overlap between the two categories with 21.02% of active behaviours falling into inactive category and 25.44% of inactive behaviours falling within the active behaviour threshold.

5. Discussion

The Actiwatch Mini® has previously been used to assess the circadian rhythm and general activity pattern of sheep (Morton et al., 2014; Piccione et al., 2011, 2007). The current study was carried out to investigate whether the Actiwatch Mini® could be used to measure behavioural activity levels. This study demonstrates that the Actiwatch Mini® can be used to detect different activity levels in an objective manner, using thresholds to process the AM recordings. There was a good level of accuracy with minimal overlap between categories when two levels were defined: active and inactive levels. The results for the medium activity thresholds demonstrate that the AM device was not able to reliably distinguish behaviour at this level. These findings are comparable to those of Müller and Schrader (2003) who used dynamic thresholds to distinguish between low and high behavioural activity levels in dairy cows using the Actiwatch® Activity Monitoring System.

This analysis of the AM data demonstrates its ability to distinguish the activity level of some behaviours, with walking being reliably distinguished from grazing, converse to the findings of others (Umstätter et al., 2008). Standing behaviours could also be distinguished from the low level lying behaviours but not from grazing behaviours. This result is likely due to standing behaviour occurring as short rests between grazing bouts. By combining standing and grazing behaviours with walking, a more practical ‘active’ category is established. This can be accurately distinguished from ‘inactive’ behaviours such as lying. Longer lying times and longer lying bouts have been found to indicate lameness and discomfort in dairy cattle (Ito et al., 2010). Changes in active behaviour could also indicate the onset of other diseases, such as pregnancy toxaemia in sheep (Buswell et al., 1986; Sargison, 2007). Thus, this method provides a more useful tool in studies assessing welfare of animals at pasture that may not undergo regular observation.

While the AM device was able to reliably distinguish between behaviours, the overlap between activity levels suggests some instances of irregularities in matching the behaviour performed with the AM recording. This limitation may be partly due to the use of instantaneous scan sampling to collect the behavioural data. Instantaneous sampling leaves time between scans for a change in behaviour to occur, such as standing to grazing. This method of data collection has previously been employed by others (O’Driscoll et al., 2008) at 5 minute intervals when validating activity monitors. They also noted a lack of agreement when using instantaneous sampling when validating data loggers in cattle. The use of shorter observation intervals may enable a higher level of accuracy to be obtained as more information would be recorded on behavioural states (Ledgerwood et al., 2010; Rurak et al., 2008).

The automatic recording devices appeared sensitive to small movements when the sheep were recorded as lying or standing. Collars were placed around the neck of sheep, so behaviours such as ruminating or self-grooming could have contributed to the higher than expected score obtained. Sakaguchi et al. (2007)

noted that neck pedometers capable of detecting oestrus in cattle, were recording the number of steps taken to be two to three times higher than those visually observed. They suggested that neck pedometers may detect and count neck activity in heifers during both walking and grazing behaviour but were able to provide a practical level of accuracy in oestrus detection. Leg mounted pedometers have a higher accuracy than neck mounted pedometers (Sakaguchi et al., 2007); however, field conditions may make their attachment and maintenance difficult for sheep.

The current AM device provides a viable method for monitoring general activity levels of sheep whilst at pasture without the need for human observations. We have demonstrated that the use of thresholds for the active and inactive behaviours provide a practical detection criterion for monitoring changes in activity levels. The ability to monitor grazing and lying behaviours whilst at pasture can provide valuable information to researchers and farmers about the current welfare of their animals. Early detection of changes in behaviour that may indicate disease, injury or distress will allow for more effective treatment and thus reduce suffering. As with other automatic detection devices further development is required.

6. Conclusion

The Actiwatch Mini® is capable of capturing data on the activity levels of sheep at pasture without restricting any of their normal movements, and can be used to distinguish between active (grazing, walking, standing ruminating and standing) and inactive (lying ruminating and lying) behaviours.

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Conflicts of interest

There are no conflicts of interest.

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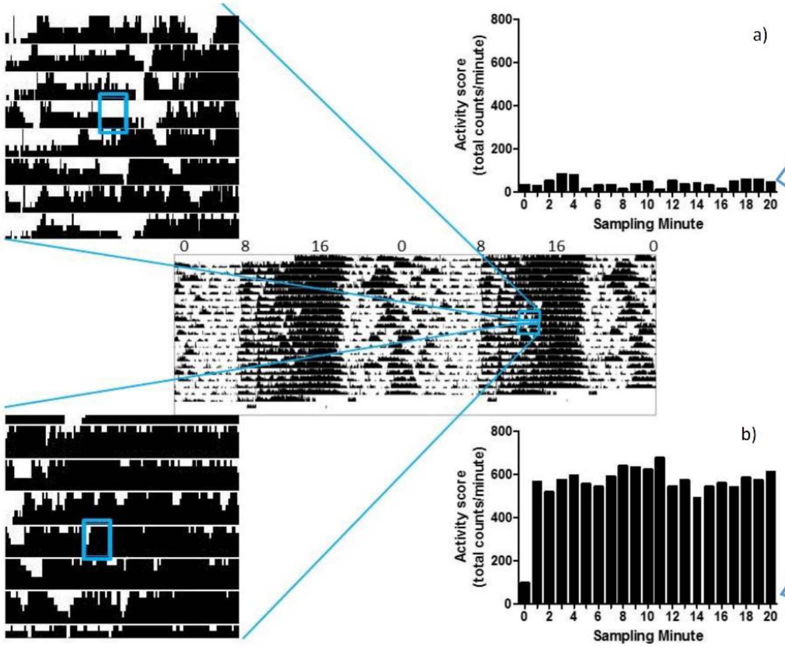
Table 1: Description of observed behaviours.

Behaviour	Description
Grazing	The animal slowly moves forward whilst searching for and ingesting grass with the muzzle close to the ground.
Walking	Animal moves forward in a four beat motion for 2 seconds or more with the head up and orientated in the direction of movement.
Standing ruminating	At rest and ruminating or in the process of regurgitating a bolus.
Standing	At rest with no jaw movement.
Lying ruminating	Lying on ground and ruminating or in the process of regurgitating a bolus.
Lying	Lying on ground with no jaw movement.



c)

Sampling Minute	Activity	AM Counts
0	Lying	32
2	Lying	50
4	Lying	75
6	Lying	30
8	Lying	12
10	Lying	47
12	Lying	51
14	Lying	41
16	Lying	15
18	Lying	56
20	Lying	42

d)

Sampling Minute	Activity	AM Counts
0	Lying	97
2	Stand ruminating	519
4	Walking	595
6	Grazing	544
8	Grazing	639
10	Grazing	622
12	Grazing	545
14	Grazing	493
16	Grazing	560
18	Grazing	585
20	Grazing	612

Figure 1. Matching of the 20 minute observation of behaviours to the double plotted actogram (centre) of one individual sheep; (a) low activity pattern and (b) medium and high activity pattern, matched to the recorded behaviours in table c) and table d) respectively.

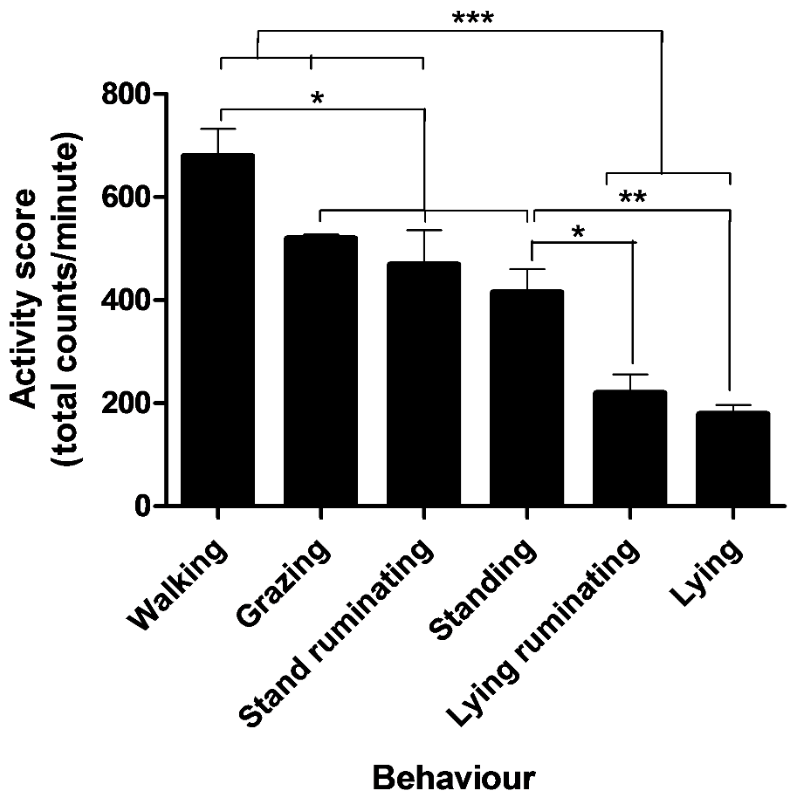


Figure 2: Activity Scores calculated from AM recordings for six individual behaviours observed in the field. Data are presented as means ± SEM. * $p<0.05$, **$p<0.01$ *** $p<0.001$

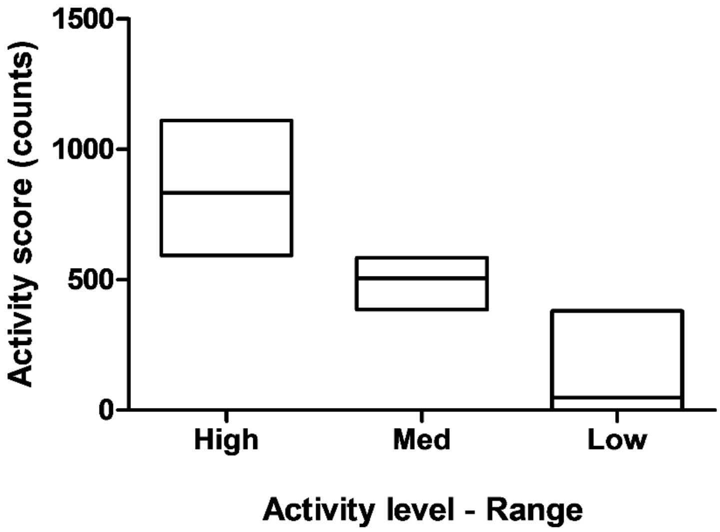


Figure 3. Calculated activity thresholds for high (walking), medium (grazing, standing ruminating, standing) and low (lying, lying ruminating) activity levels. Lines represent the mean activity scores and boxes represent the calculated thresholds for each activity level.

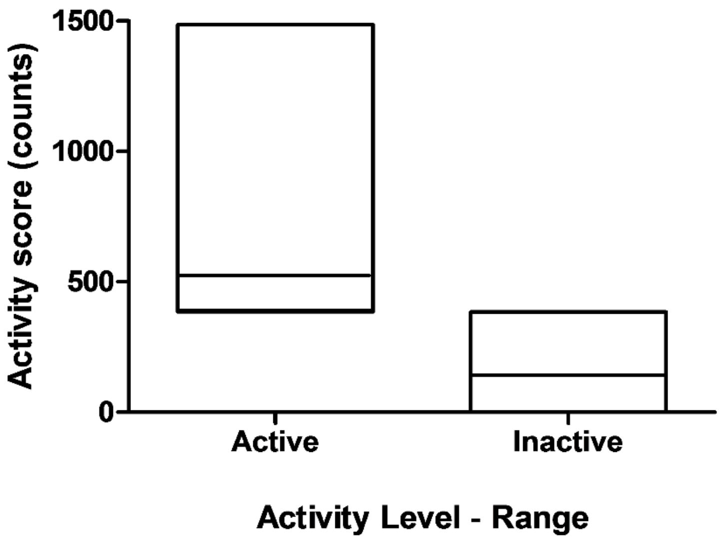


Figure 4. Calculated activity thresholds for the ‘Active’ behaviours (walking, grazing, standing ruminating, standing) and inactive behaviours (lying, lying ruminating). Lines represent the mean activity levels and boxes represent the thresholds and range of each activity level.