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Quantification of activity in domestic cats (*Felis catus*) by accelerometry

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ABSTRACT

Accelerometers (Actical® 'Mini Mitter' (MMA)) have been used to assess the activity of domestic cats (*Felis catus*), and have been validated against measures of observed activity in this species; however, previous validation trials have had very small sample sizes and have not considered inter-individual variation. The present study aimed to quantify the magnitude of inter-individual variation by validating MMAs against observed activity in a larger number of cats. A total of 288 h of concurrent MMA and observed activity data (percentage of time spent active) were collected from 12 cats and assessed using four defined sampling periods: 1 min, 1 h, 6 h and the 1 h moving average at 10 min intervals. There was a strong linear correlation ($P < 0.001$) between MMA and observed activity data for the combined data set for all four sampling periods; however, there was considerable variation between cats. The MMA and observed activity data of individual cats were also highly correlated over the 10 min (range of Pearson's correlations: 0.65–0.98, $P < 0.001$), 1 h (0.68–1.0, $P < 0.001$), 6 h (0.92–1.0, $P < 0.05$, except for cat 12 where $P > 0.05$) and 1 h moving average (0.81–0.99, $P < 0.001$) sampling intervals. The 1 h moving average at 10 min intervals appeared to be the best sampling interval as it maximised the strength of the correlation while maintaining sufficient information to follow patterns of activity over the 24 h. Ultimately, the current study showed that MMAs can be used to accurately quantify the activity of domestic cats; however, there was a considerable amount of variation between cats, and thus each cat should be considered independently and serve as their own control when assessing any changes in activity levels.

1. Introduction

Monitoring the physical activity of animals can provide an insight into their behaviour, health and wellbeing. Changes in overall activity have been linked to illness (Lascelles et al., 2007; Brown et al., 2010), injury, hunting, stress/stereotypical behaviours (Papailiou et al., 2008), and energy expenditure (Hartel et al., 2011) and reproductive events such as oestrus (Gerall et al., 1973; Wielebnowski and Brown, 1998; At-Taras and Spahr, 2001; Moreira et al., 2001; Brown et al., 2002; Cornou, 2006).

The activity of domestic cats (*Felis catus*) has predominantly been assessed in order to determine the effectiveness of pain therapy for conditions such as osteoporosis, with the overall activity of cats increasing following treatment with non-steroidal anti-inflammatory drugs (NSAIDs) (Lascelles et al., 2007). There may also be an increase or change in the overall activity of domestic cats and other felids during oestrus (Foreman, 1997; Wielebnowski and Brown, 1998; Moreira et al., 2001; Brown et al., 2002), and while many felid species lack overt behavioural indicators of oestrus there are several behaviours that are generally expressed more frequently during oestrus appear to correlate with an increase in activity (Foreman, 1997; Wielebnowski and Brown, 1998; Moreira et al., 2001; Brown et al., 2002; Henriksen et al., 2005).

A logistic challenge has been the accurate quantification of activity without continuous, labour-intensive and potentially intrusive behavioural observation. Recent advances in remote sensing technologies, such as accelerometry, have enabled the accurate quantification of activity. Over the past decade accelerometer technology has advanced considerably, with the devices becoming smaller, cheaper and easier to use. Consequently, accelerometers are increasingly used as a tool to quantify activity in a variety of species including humans (Hendelman et al., 2000; Trost et al., 2000; Kumahara et al., 2004; Penpraze et al., 2006; Staudenmayer

Abbreviations: MMA, Actical® Mini Mitter accelerometer; IR, infra-red; NSAIDs, non-steroidal anti-inflammatory drugs.

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et al., 2009; Hartel et al., 2011), rhesus monkeys (*Macaca mulatta*) (Papailiou et al., 2008), dairy cows (At-Taras and Spahr, 2001; McGowan et al., 2007), dogs (*Canis familiaris*) (Hansen et al., 2007; Brown et al., 2010; Yam et al., 2011; Singh, 2013), and cats (Watanabe et al., 2005; Lascelles et al., 2007; Lascelles et al., 2008).

Only one study has thus far specifically validated the use of accelerometers to quantify overall activity in cats (Lascelles et al., 2008). These authors used Actical® 'Mini Mitter' accelerometers (MMAs) to monitor the activity of cats, and then compared the results against simultaneously observed activity (distance moved and mobility). While their study found a strong correlation between MMA and observed activity, their small sample size ($n = 3$) precluded investigation of inter-individual variation.

The current study aimed to quantify the magnitude of inter-individual variation by validating MMAs against observed activity with a larger number of cats ($n = 13$).

2. Methods

2.1. Animal husbandry

Thirteen healthy adult female cats (11 intact and two spayed) aged from 2 to 13 years (mean ± SD, 7.7 ± 3.6 years) and weighing 2.8 to 4.4 kg (mean ± SD, 3.3 ± 0.5 kg) were used in this study. The cats were housed in three purpose-built colony cages at the Centre for Feline Nutrition, Massey University, Palmerston North, New Zealand (175°38′E, lat. 40°22′S, long.), in mixed-sex groups of seven to 10 animals, of which three to five were studied per cage. They were fed a complete and balanced (Association of American Feed Control Officials AAFCO, 2009) commercial moist (canned) feline diet (Heinz Wattie's Ltd., Hastings, New Zealand) and had *ad libitum* access to water. The husbandry of the cats complied with Massey University ethics committee protocol number 12/12.

2.2. Activity monitoring

Behavioural activity was recorded in real-time at 200 frames/s using a TechView H.264 digital video recorder security camera system (Tech Brands: Electus Distribution, Auckland, New Zealand) that could detect both visible and infra-red (IR) light, enabling continuous observation of the cats under a natural photoperiod. Behaviours were categorised as either active (locomotion, rolling, rubbing, playing, and climbing) or inactive (sleeping, resting/stationary, urinating/defecating drinking, eating, grooming and scratching) and continuous duration sampling over the 24 h (analysed in 10 min blocks) was used to determine the amount of time spent active by each cat. Activity was measured concurrently using MMAs (Mini Mitter, Bend, OR, USA), which each measured 28 mm × 27 mm × 10 mm and weighed 17 g. These MMAs used an omnidirectional accelerometer to detect movement in three planes (craniocaudal, mediolateral and vertical). An acceleration force produced a voltage output that was amplified and converted into a digital value that was corrected for the effects of gravity (Lascelles et al., 2008). The values were then summed for a defined period (epoch), resulting in a total activity count for that period. We used a 15 s epoch.

2.3. Experimental design

A unique pattern of reflective tape was placed on each MMA so that the cats could be identified individually under IR light. The MMAs were then attached to the collars of the cats and positioned ventrally. The cats were returned to their normal enclosures which were under continuous video surveillance. Accelerometer and video data were collected from each cat over the following 24 h.

2.4. Data evaluation and statistical analysis

The raw activity data were downloaded from the MMAs using an Actireader device (Mini Mitter., Bend, OR, USA), and imported into an excel spreadsheet for analysis. Activity data (total MMA count/15 s) from each cat were summed to provide the total accelerometer counts for four sampling periods: 10 min; 1 h; 6 h; and a calculated 1 h moving average at 10 min intervals (McGowan et al., 2007). The total accelerometer counts for these four sampling periods were then compared against the percentage of time spent active (observed activity) for the corresponding period of video data.

All statistical analyses were conducted using R version 3.1.1 (R Foundation for Statistical Computing, Vienna, Austria) and an $\alpha \leq 0.05$. Pearson's correlation coefficients were used to examine the relationships between the MMA counts and the percentage of time spent active for each cat and for the combined data set over the four sampling periods. The correlation coefficients for each of the four sampling periods were then compared to determine which sampling interval yielded the highest correlation. One cat (cat 3) had dramatically higher levels of activity when compared to the other cats, so analyses were conducted that included and excluded her data. In addition, one of the MMAs (fitted to cat 13) recorded activity counts that were substantially higher than recorded by any of the other devices and were not reflected in the cat's activity in the video data. It was concluded that the device had malfunctioned, so data from this cat were excluded from the study.

3. Results

A total of 288 h of concurrent MMA and videoed activity data were collected and are summarised in Table 1. The MMA activity data and percentage of time spent active (videoed/observed activity) for the combined data set were strongly correlated for all four sampling periods ($P < 0.001$) (Table 2). Cat 3 had a significant ($P < 0.001$) effect on the strength of the correlation between MMA and observed activity. When the data from this cat were removed from the analysis the correlation coefficients between MMA and observed activity declined by 14.9%, 15.5%, 13.3%, and 12.4% for the 10 min, 1 h, 6 h and 1 h moving average sampling intervals, respectively (Table 2).

The MMA and observed activity data of individual cats were also highly correlated over the 10 min ($P < 0.001$), 1 h ($P < 0.001$), 6 h ($P < 0.05$, except for cat 12 where $P > 0.05$) and 1 h moving

Table 1
The percentage of time spent active and total MMA counts of individual cats for the 24 h study period. The data from Cat 13 were excluded from the study as the MMA malfunctioned and recorded extremely high activity counts (*).

Cat	Total time spent active (min/24 h)	% time active/24 h	Total MMA count/24 h
1	16.9	1.2	18437
2	18.9	1.3	30369
3	285.1	19.8	421369
4	49.3	3.4	67364
5	38.3	2.7	81896
6	37.1	2.6	63883
7	27.0	1.9	68159
8	64.0	4.4	128252
9	20.4	1.4	49395
10	47.7	3.3	41804
11	37.9	2.6	79507
12	26.6	1.9	101271
13	–	–	4639737*

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