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Evaluation of a wireless activity monitoring system to quantify locomotor activity in horses in experimental settings

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Summary

Reasons for performing study: Methods of evaluating locomotor activity can be useful in efforts to quantify behavioural activity in horses objectively.
Objectives: To evaluate whether an accelerometric device would be adequate to quantify locomotor activity and step frequency in horses, and to distinguish between different levels of activity and different gaits.
Study design: Observational study in an experimental setting.
Methods: Dual-mode (activity and step count) piezo–electric accelerometric devices were placed at each of 4 locations (head, withers, forelimb and hindlimb) in each of 6 horses performing different controlled activities including grazing, walking at different speeds, trotting and cantering. Both the activity count and step count were recorded and compared by the various activities. Statistical analyses included analysis of variance for repeated measures, receiver operating characteristic curves, Bland–Altman analysis and linear regression.
Results: The accelerometric device was able to quantify locomotor activity at each of the 4 locations investigated and to distinguish between gaits and speeds. The activity count recorded by the accelerometer placed on the hindlimb was the most accurate, displaying a clear discrimination between the different levels of activity and a linear correlation to speed. The accelerometer placed on the head was the only one to distinguish specifically grazing behaviour from standing. The accelerometer placed on the withers was unable to differentiate different gaits and activity levels. The step count function measured at the hindlimb was reliable but the count was doubled at the walk.
Conclusions: The dual-mode accelerometric device was sufficiently accurate to quantify and compare locomotor activity in horses moving at different speeds and gaits. Positioning the device on the hindlimb allowed for the most accurate results. The step count function can be useful but must be manually corrected, especially at the walk.

Keywords: horse; locomotor activity; step count; accelerometer; activity count

Introduction

Many drugs are known to modulate locomotor activity in horses. For instance, opioids have been reported to increase locomotion and evoke excitation [1]. This increase in locomotor activity can vary depending on the subjects and the experimental conditions [2–7]. Part of this variability may also derive from the method of assessment. Different methods of quantifying locomotor activity include using a subjective activity score based on direct observation of the subjects [6], step counting [3–5] and using an accelerometer strapped to a body part of the animal to detect movements and their intensity [8–10]. All of these methods are able to detect variations in locomotor activity, but the relationship between the quantification method and the actual locomotor activity has not been validated in horses, particularly when considering different movement intensities, different movement types and different recording locations.

An activity monitoring system (Animal ActiCal[a]) that includes an accelerometer and provides both an activity and a step count has recently been developed. This accelerometric device provides a single output value per unit of time for the activity count based on the total activity recorded by an omnidirectional sensor and has been shown to adequately quantify locomotor activity in dogs [11], cats [12] and rhesus monkeys [13]. However, no extensive investigation has been reported in horses.

The aim of this study was to evaluate whether the activity count and step count provided by the accelerometric device can facilitate the evaluation of locomotor activity in horses. The study was based on the hypothesis that quantification of locomotor activity by means of this activity datalogger will enable discrimination between different gaits and that step frequency will be appropriately determined in horses.

Materials and methods

Animals

Six geldings, obtained from a homogeneous population of Swiss Warmbloods used for schooling in a military centre (Nationales Pferdezentrum [National Equine Centre; NPZ], Bern, Switzerland), with a mean $\pm$ s.d. age of 14 $\pm$ 4 years, body weight of 612 $\pm$ 50 kg and height of 170 $\pm$ 5 cm were enrolled in this study. The horses were kept in single boxes within large stables. All the horses were healthy, routinely ridden and accustomed to the various manipulations and activities relevant to the study.

Wireless activity monitoring system

The accelerometric device is a small datalogger that measures 37 $\times$ 28 $\times$ 10 mm in size and weighs 17 g. It is constructed to detect body accelerations in all directions using an omnidirectional piezo–electric accelerometer, which detects variation from the normal force of gravity. The device measures at 32 Hz and records total raw electrical activity. Dedicated software (Actical Version 3.10[b]) then derives a cumulative activity count for periods of 5 s and a total step count over periods of 1 min. A detailed description of the monitor and its mechanism of action has been given elsewhere [14]. Briefly, the accelerometer is powered by a small lithium battery and recording settings (schedule, length of period and recording mode) are programmed using dedicated software and a wireless communication unit. The device is then strapped to the animal and recording starts automatically. After recording, the device is retrieved from the subject and the recordings are downloaded and saved. When it is used in animals, the sensor is protected in a small metal box (67 $\times$ 37 $\times$ 17 mm).

Data collection

Each horse was fitted with 4 separate accelerometers. The boxed sensors were attached on each horse at 4 different locations that would not interfere with locomotion. One sensor was fixed tightly with tape (Tesa Extra Power Perfect Tape[c]) at the middle of the crownpiece of the halter on the head. Another was placed 10 cm behind the crest of the withers, tightly fixed with tape to a thoracic belt. The third box was placed between the heel bulbs within a tight bandage around the pastern and coronary band of the left forelimb. The fourth was secured with Velcro to the lateral aspect of a soft splint boot[d] worn on the left hindlimb. Data were recorded using the recommended software settings. When all the accelerometers had been attached to the horse and activated, a series of trials were carried out under the following conditions:

stage 1: moving freely in a paddock for 20 min;
stage 2: grazing on a pasture for 5 min;
stage 3: walking on a hand lead for 3 min;
stage 4: trotting on a lunge line for 5 min (at a diameter of approximately 20 m);
stage 5: cantering on a lunge line for 3 min (at a diameter of approximately 20 m), and
stage 6: walking alone in a horse walker (approximately 40 m in diameter) at 5 different speeds (3, 4, 5, 6 and 8 km/h). For each horse, the sequence of the different speeds was randomised independently.

The horses were lunged with a simple halter, without any other equipment. During *stages 1–5*, continuous videorecordings were obtained to allow for detailed retrospective observation. Upon the successful completion of all stages, the boxed accelerometers were removed and the data were downloaded.

Step frequency

In order to validate the step frequency determined by the device, this outcome (calculated) was compared with the step frequency obtained manually (measured). For this purpose, the measured and calculated values were compared for periods of 1 min. For each horse and at each of the 4 accelerometer locations, a pair of recordings was obtained for 3 periods of 1 min at 4 km/h (*stage 6*), 6 km/h (*stage 6*), trot (*stage 4*) and canter (*stage 5*). Therefore, a total of 288 paired measurements were collected and compared (6 horses, 4 locations, 4 speeds, 3 periods). For *stages 4* (trot) and *5* (canter), measured step frequencies were obtained by direct observation of the videos. No continuous video was obtained during *stage 6* (walking alone in the horse walker at different speeds). Therefore, the continuous graph for the raw electrical data of the accelerometer placed on the hindlimb was used because each impact of the foot striking the floor could be clearly identified. Concordance between video and raw electrical data was verified during *stage 3* (walking on a hand lead) by comparing step counts over 3 periods of 1 min for each horse (18 pairs in total).

Data analysis

Data for the 5 s activity counts are presented as the median (interquartile range). Differences between stages as well as the effect of time were tested using a Friedman analysis of variance (ANOVA) on ranks for repeated measures followed by a Student–Newman–Keuls test for multiple comparisons. Correlations between walking speed and activity counts were determined using a Spearman rank order correlation followed by linear regression. The ability of the activity counts to discriminate between the different stages was evaluated with receiver operating characteristic (ROC) curves based on the area under the curve (AUC). The ability of the datalogger to quantify the step count was assessed with difference plots (Bland–Altman) for repeated measures plotting the difference between the manually counted and measured step counts (fixed bias) against the average of both measures [15]. A percentage error plot (proportional bias) was obtained and absolute values of both percentage errors and 1.96 SD (95% limits of agreement) of $\leq$3% were considered acceptable. The analyses were performed with the dedicated statistical software (Sigmaplot Version 12.0[e] and MedCalc Version 14.12.0[f]). Statistical significance was set at $P \leq 0.05$.

Results

The 5 s activity counts were recorded at each stage at all 4 sensor locations (Table 1). Values for the activity counts increased with gait and speed at all 4 recording locations. Differences and their statistical significance are listed in Table 1. The accelerometric device placed on the hindlimb produced activity count values that differed significantly between all stages (Fig 1) except between free movement in the paddock (*stage 1*) and grazing (*stage 2*). The accelerometer placed at the head also showed good sensitivity (Table 1); the head was the only location at which the sensor was able to distinguish between free movement in the paddock (*stage 1*) and grazing (*stage 2*), but it did not record significantly different activity counts between grazing (*stage 2*) and slow walking (3 km/h, *stage 6*), or between rapid walking (8 km/h, *stage 6*) and trotting (*stage 4*). Activity counts obtained at both the forelimb and withers did not differ significantly between walking at 4 and 5 km/h, respectively, or between walking at 6 and 8 km/h, respectively (Table 1).

When measured on the hindlimb, the activity count was positively and linearly correlated (R^2 = 0.925) (Fig 2) with the speed of walking within the horse walker (3, 4, 5, 6 and 8 km/h). Data obtained at the other locations showed significant positive correlations between walking speed and activity counts ($P<0.05$; head, ρ = 0.77; withers, ρ = 0.87; forelimb, ρ = 0.41), but the correlation was not linear (head, R^2 = 0.32; withers, R^2 = 0.71; forelimb, R^2 = 0.08).

Analysis of the ROC curves was used to evaluate whether a single value for the activity count could be used to discriminate between the different stages in all horses (Table 2). For activity counts measured on the hindlimb, discriminative cut-off values were found between each gait (stand, move, walk, trot and canter) with maximum accuracy (AUC: 1.00). All activity counts of <415 were obtained in standing or walking horses; all counts of 415–2131 were obtained in trotting horses, and all counts of >2131 were obtained in cantering horses (Table 2). Activity counts measured on the forelimb differentiated perfectly between standing and walking, but with less specificity between walking and trotting, as well as less sensitivity between trotting and cantering (Table 2). When the accelerometer was placed on the head, both sensitivity and specificity were decreased for all comparisons (Table 2). As an example, the ROC curve in Figure 3 indicates that a value of 330 for the 5 s activity count measured on the head is able to discriminate between trotting and cantering. Finally, the measurements obtained at the withers clearly differentiated between walking and trotting, but not between trotting and cantering (Table 2).

For each of the 18 pairs of data obtained at the walk, the step frequency measured by observation of the total raw electrical data agreed exactly with the reference value (step frequency measured by observation of the simultaneous videos), validating this measurement method. In comparison with the measured value (video or raw data), the step frequency calculated by the accelerometric device was doubled at the walk for all 4 locations, as well as at the trot for all locations except the hindlimb. By contrast, during canter, the accelerometer measured step frequency correctly at all locations. After correction for the doubling, Bland–Altman plots derived from recordings on the hindlimb showed low percentage errors as well as acceptable limits of agreement at all gaits (Table 3, Fig 4). Percentage errors were high and limits of agreement were not acceptable for the measured step frequency at the other 3 sensor locations (Table 3).

Because of the doubling at the walk, step frequency recorded at the hindlimb was in the same range as for trot and canter (Fig 5a), although it must have been around half (Fig 5b). By plotting the measured step count against the activity count (Fig 5c), it became possible to identify the measurements recorded at the walk (low range of activity count) and to apply the halving factor.

Discussion

The activity count measured by the accelerometric device (Animal ActiCal[a]) was able to quantify locomotor activity at each of the 4 locations at which the device was placed and to distinguish between gaits and speeds. The accelerometer placed on the hindlimb provided the most discriminative information under all studied conditions. It

TABLE 1: Activity counts (n units) recorded by the accelerometric device (ActiCal[a]) in 6 horses at 4 different sensor locations during 6 different stages at different gaits

		Median (IQR) activity counts by location of sensor			
Stage		Head	Withers	Forelimb	Hindlimb
1	Free in paddock	0 (0–0)[1]	0 (0–0)[1]	0 (0–0)[1]	0 (0–0)[1]
2	Grazing	21 (9–29)[2]	0 (0–0)[1]	0 (0–17)[1]	0 (0–62.5)[1]
3	Walking	64 (54–146)[4]	110 (79–136)[5]	267 (178–400)[4]	729 (636–837)[6]
4	Trotting	239 (190–309)[7]	280 (163–325)[6]	535 (353–895)[5]	1796 (1687–1969)[8]
5	Cantering	487 (390–597)[8]	311 (194–589)[6]	868 (763–1418)[6]	3198 (3056–3383)[9]
6 (Walking at constant speed)	3 km/h	20 (14–63)[2]	16 (6–25)[2]	150 (110–271)[2]	346 (317–358)[2]
	4 km/h	51 (42–112)[3]	54 (13–64)[3]	179 (138–325)[3]	453 (413–458)[3]
	5 km/h	83 (70–165)[5]	91 (45–114)[4]	170 (130–355)[3]	520 (504–552)[4]
	6 km/h	132 (106–267)[6]	141 (74–153)[5]	219 (177–401)[4]	635 (588–679)[5]
	8 km/h	212 (149–410)[7]	173 (127–240)[6]	260 (189–538)[4]	959 (908–1055)[7]

Exponent numbers represent groups showing statistically significant differences (P≤0.05). For each location of the sensor, different exponent numbers represent significantly different activity counts between stages. Exponent numbering indicates incremental activity count. IQR = interquartile range.

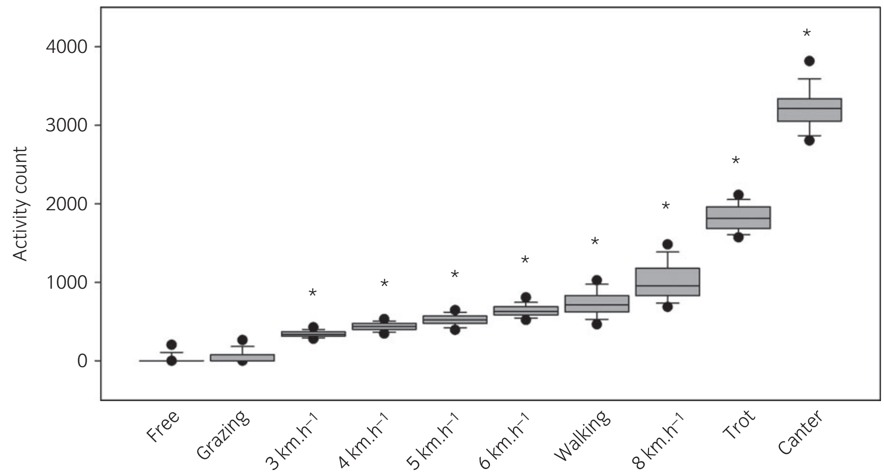

Fig 1: Activity counts (median, interquartile range [percentiles 5–95]) recorded by the accelerometric device (ActiCal[a]) located on the hindlimb in 6 horses performing different activities (grazing, moving freely, walking, trotting, cantering). *represents a statistically significant difference from the group to the immediate left.

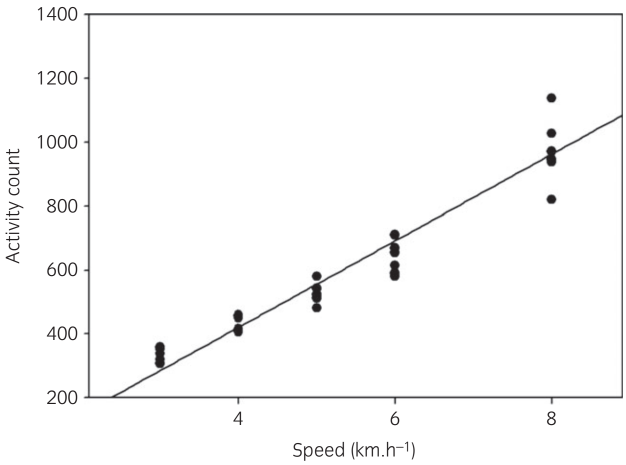

Fig 2: Linear correlation between walking speed and activity count measured by the accelerometric device (ActiCal[a]) located on the hindlimb in 6 horses. Data are represented as the median of the activity count summed over 5 s. The linear equation was valid for speeds of 3–8 km/h and estimated the 5 s activity count to ([125*speed]-68).

allowed for complete discrimination among all gaits both at the level of the individual, as well as among all horses, and complemented the step count to identify when the halving factor should be applied for the walk. Recording devices placed at other locations performed well, but presented some weaknesses.

The impact of using different recording locations for accelerometers has not yet been investigated in horses during behavioural studies. In prior equine studies, accelerometer devices have been placed on the neck, [8,9,16], the forelimb [7,10,16] and the hindlimb [7,17,18]. Placement on the withers has not yet been reported. The current study showed that devices at some locations are better able to discriminate between different levels of activity, gait and speed than devices at others. Placement on the hindlimb provided very high sensitivity and specificity for the different levels of activity, with a linear correlation to walking speed.

It might be expected that the recording of movements of the trunk with a device placed on a thoracic belt will be less influenced by atypical gaits, kicking, scratching, head-shaking or other non-locomotor behavioural manifestations of the head and limbs. Placement of accelerometers at the waist is standard in humans [19]. However, there was a large overlap in activity counts recorded at the withers for different levels of activity in the different horses, and measurements allowed for only rough discrimination among standing, walking and trotting. In the present authors' opinion, there is little chance that walking and trotting in straight lines rather than large circles will improve this output, but this has not been investigated.

TABLE 2: Summary of the area under the curve (AUC) (cut-off value), sensitivity and specificity of the receiver operating characteristic curves for the ability of the activity count recorded by the accelerometric device (ActiCal[a]) to distinguish between standing, moving, walking, trotting and cantering in 6 horses at 4 different sensor locations

	AUC (cut-off value), sensitivity and specificity by location of sensor			
Stages under comparison	Head	Withers	Forelimb	Hindlimb
Stand/move	0.9 (>0), 83%, 93%	0.942 (>0), 88%, 100%	1 (>0), 100%, 100%	1 (>0), 100%, 100%
Stand/walk	0.958 (>0), 97%, 93%	0.942 (>0), 88%, 100%	1 (>0), 100%, 100%	1 (>0), 100%, 100%
Walk/trot	0.989 (>72), 100%, 88%	1 (>69), 100%, 100%	0.937 (>259), 100%, 83%	1 (>415). 100%, 100%
Trot/canter	0.934 (>330), 93%, 80%	0.639 (>321), 45%, 83%	0.846 (>652), 92%, 80%	1 (>2131), 100%, 100%

The AUC is between 1 (perfect classification) and 0.5 (no discrimination). The cut-off value is the value of the activity count that best discriminates between both states.

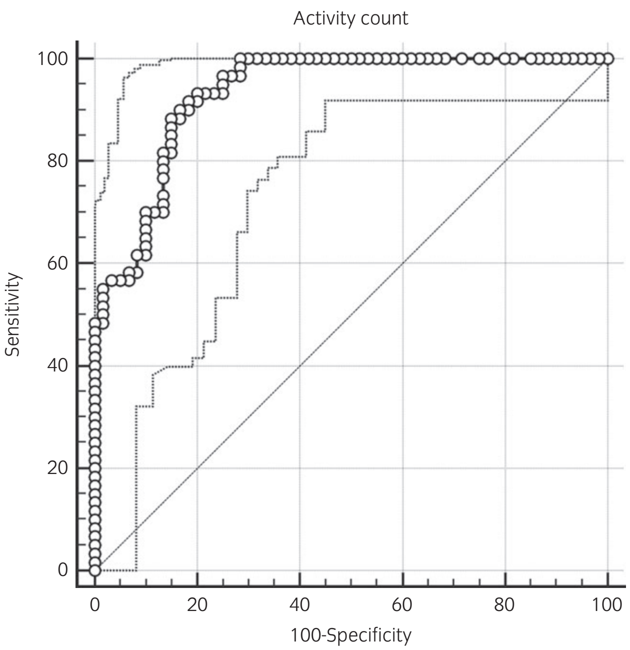

Fig 3: Example of a receiver operating characteristic curve (with confidence interval [CI]) that distinguished between horses trotting and cantering, respectively, based on the value of the activity count measured by the accelerometric device (ActiCal[a]) placed on the head in 6 horses. For this curve, the area under the curve was 0.934, standard error 0.021, 95% CI 0.873–0.971, P<0.0001, sensitivity 93.3% (6.7% of false negative), specificity 80% (20% of false positive) with a discrimination criterion for the activity count of 330.

This lack of sensitivity at some locations may predict that differences in slow-motion movements may become difficult to detect, even if the device is placed on the hindlimb. This may require further investigation.

The head has been used previously in horses for the placement of accelerometer devices [8,9,16]. In the current study, recordings obtained at the head did not allow for clear discrimination between the different levels of activity, performed worse than those obtained at the hindlimb and findings did not correlate satisfactorily with walking speed. Nonetheless, the recordings were of sufficient specificity to distinguish between different gaits. In addition, placement on the head specifically recorded higher activity counts during grazing compared with placements at the other locations. This is probably because most movement during grazing involves the head and there is minimal movement of the rest of the body. If grazing or specific movements generated by eating are not of interest in the investigation, the head should probably not be considered as the primary sensor location. Placement of an accelerometer on the forelimb was also reported in previous studies [7,10,16]. In this study, the forelimb performed less well than the hindlimb for increasing speed and gaits. This is probably because of the different dynamics and roles of the fore- and hindlimbs during equine locomotion. The forelimb may show more impact

TABLE 3: Summary of the Bland–Altman analysis for repeated measures comparing the step count measured by the accelerometric device (ActiCal[a]) placed at 4 different locations with the manually calculated step count in 6 horses performing different activities

	Head	Withers	Forelimb	Hindlimb
All stages	5.9% (±39.5)	-8.1% (±50.9)	11.1% (±58.9)	-0.2% (±2.0)*
4 km/h	2.8% (±32.8)	-3.5% (±79.2)	8.3% (±56.4)	-0.4% (±2.9)*
6 km/h	-2.3% (±5.2)	-30.5% (±31.2)	17.2% (±58.4)	0.1% (±2.0)*
Trot	26.8% (±53.0)	7.1% (±19.2)	31.6% (±48.4)	-0.1% (±1.2)*
Canter	-2.3% (±5.2)	-30.5% (±31.2)	17.2% (±58.4)	0.1% (±2.0)*

Data are represented as mean percentage error between real and measured values (±1.96 SD). Negative values occur when the step count measured by the accelerometric device is higher than the actual step count.
*Represents acceptable error (-3% <percentage error <+3%, and 1.96 SD < 3%).

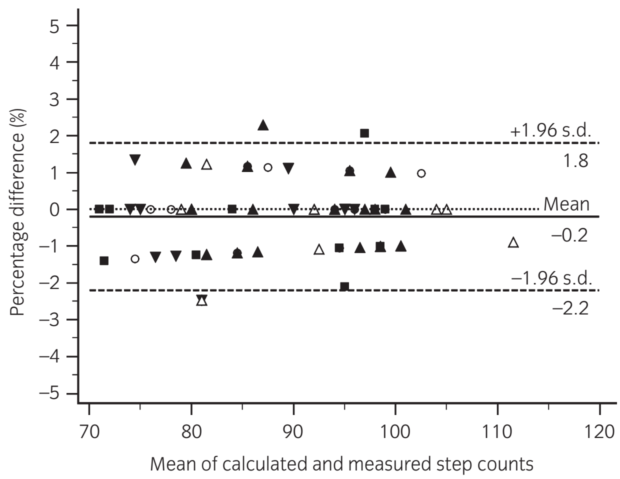

Fig 4: Example of a Bland–Altman analysis for repeated measures comparing the step count measured by the accelerometric device (ActiCal[a]) placed at the hindlimb with the manually calculated step count in 6 horses performing different activities (grazing, moving freely, walking, trotting, cantering). Symbols represent the 6 different horses. The percentage difference is calculated as ([(real step count-measured step count)/real step count] × 100). Continuous lines represent the mean percentage error and dashed lines the 95% limits of agreement (+*– 1.96 SD). Biases were deemed acceptable if absolute values of both percentage error and 1.96 SD were below 3%.

shock (signal noise) and less acceleration than the hindlimb. Differences may also relate to the placement of the accelerometer at the heel on the forelimb vs. at the cannon bone on the hindlimb.

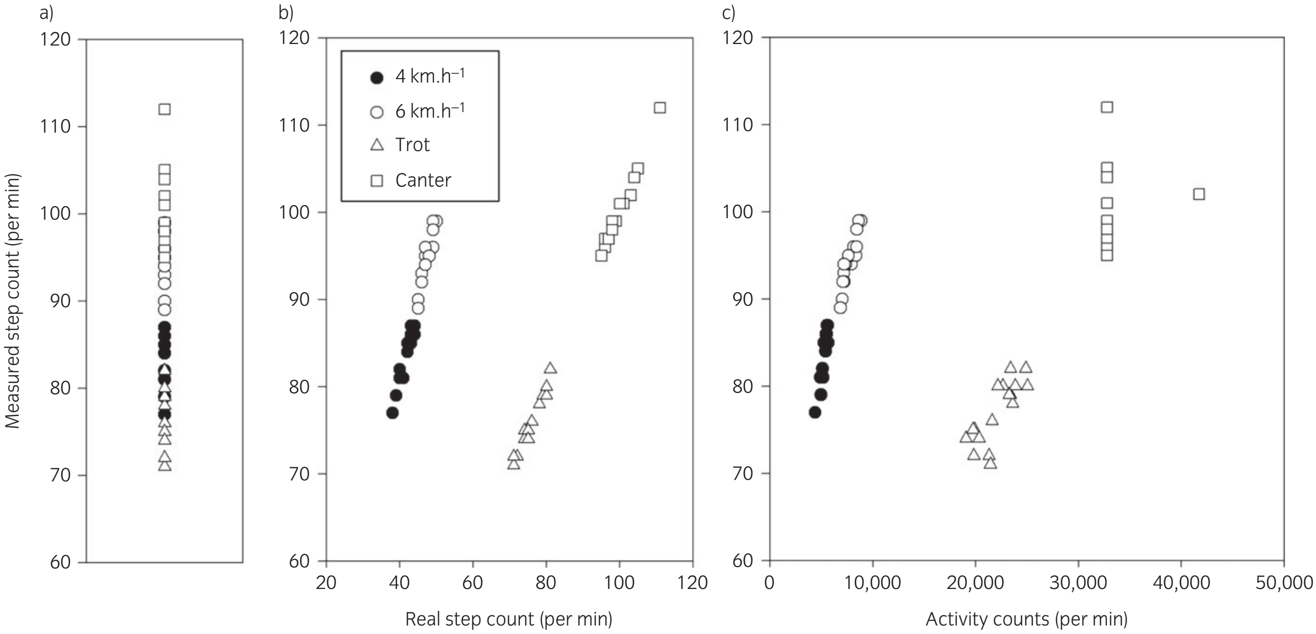

Fig 5: Example of the adequacy of the step count measured by an accelerometric device (ActiCal[a]) placed on the hindlimb in 6 horses moving through 3 different gaits. (a) The step count measured by the accelerometric device (ActiCal[a]) in walking horses overlaps with values obtained at the trot and canter, suggesting inadequate quantification. (b) In comparison with manually calculated step counts, values are suitable but doubled in walking horses. (c) The step count in combination with the activity count discriminates between gaits and identifies walking horses when doubling is taken into account as appropriate.

Accelerometers have been used in horses to monitor various movement patterns in order to detect lameness [20] or to evaluate the influence of ground surface type on locomotion [21,22]. Piccione and colleagues provided evidence for the strong daily rhythmicity of motor activity in horses using the Actiwatch activity datalogger (Mini-mitter; Philips Respironics), a former version of the ActiCal[a] device, strapped to the animals' necks [8]. To validate the relevance of the output of the accelerometers, horses were guided through a series of standard activities as reported previously in dogs [11,23,24] and in horses [10]. The selected standard activities included controlled conditions such as defined gaits [10,23,25] and the use of a horse walker with controlled speeds. For the same purpose, Preston and colleagues used a treadmill to validate an accelerometer in dogs [24]. The aim of the current study was to evaluate the ability of the ActiCal[a] device to discriminate among gaits and different levels of locomotor activity; in these respects, the device proved to be very accurate when placed on the hindlimb.

The accelerometric device is simple to fix to a halter or thoracic belt, but special attention should be paid to avoid displacements which may induce variations in acceleration values and invalidate comparisons over time. Placing the accelerometer within a bandage at the hoof bulb of the forelimb required more preparation time than placing the device at the other locations. Fixation to the lateral aspect of the hindlimb using Velcro was easy and repeatable. The left fore- and hindlimbs were chosen because most horses are normally handled from the left side. Particular attention was paid to the placement and stability of the sensors over time and therefore the low performance of the devices placed on the withers, head and forelimb is not considered to have resulted from inappropriate fixation.

The different stages of activity were carried out in large areas in order to produce movements of large amplitude over prolonged periods (several minutes). The results presented here are not sufficient to determine whether this method is accurate for movements of small amplitude in a confined area, such as moderate drug-induced locomotor activity in a box stall. The horses were placed in a paddock in order to test whether quiet moments with minimal movement could be discriminated from events of excitation and increased locomotor activity. However, the horses behaved very quietly and no difference was observed between data obtained in this condition and data obtained during grazing. This highlights the importance of validating sensors and recording locations for the behaviour of interest.

When measuring at the withers, the activity count output showed wide variability among subjects. Nevertheless, the activity count measured at the withers followed the level of activity when datasets for each horse were considered independently, but values could not be compared among horses. The variability among subjects was lower at the head, and much less at the limbs. Data obtained from one horse at the forelimb showed acceleration values up to five times higher than those for other horses (both raw acceleration and activity count were increased). This feature was present at all stages and may indicate that this horse had a particularly dynamic motion of the forelimb. No particular events or unusual gaits that might explain this difference were observed in the videorecordings. Accelerometers are very sensitive and differences in individual gaits such as in propulsion or limb movements may include individual variability, even if this cannot be clearly recognised by visual observation.

The step count has often been reported to quantify locomotor activity in horses. It has been obtained by direct visual observation, which is time-consuming [4,5], or by using an automated system [2,7]. For instance, step counters have been used in horses to estimate motor laterality in grazing horses [26] and to monitor the activity of mares immediately before parturition [16]. However, these step-counting devices have not yet been evaluated in horses under different gaits and situations. In the current study, the step count function of the accelerometric device was compared with a manually measured step count obtained from video observation or, alternatively, from raw data from the accelerometer. Findings indicate that the step count measured by the accelerometric device placed on the hindlimb was the most accurate, but was not sufficient in itself to discriminate between the different gaits because step frequency was doubled at the walk. When information from the step and activity counts was combined, it was possible to discriminate between the gaits accurately and to correct the step count appropriately.

The reason why step frequency was doubled during the walk is unknown because the authors lack information about the ActiCal[a] device calculation algorithm. Therefore, some of the factors used to convert the raw accelerometry data into the final step count may have been overlooked. Observation of the acceleration raw data, despite differences in morphology among the 4 recording locations, always revealed a clear peak in amplitude for each step, but during the walk a second peak of smaller amplitude was also recorded. The same was observed in most cases during trot, but not during canter. Firstly, this second peak may be generated by motion of the contralateral limb. Secondly, each walking step may contain 2 events of acceleration that are recorded by the sensor as 2 different steps. Further investigation is required to confirm whether other movements such as lifting and dropping the foot may be counted as different steps. Lastly, the step frequency of walking horses may be too low (around 45 steps/min) for the normal range of this device, which was originally designed for use in man. Esliger and colleagues reported 95 steps/min for a slow walk in humans [19]. Earlier, Le Masurier and Tudor-Locke had reported some degree of inaccuracy at decreasing walking speeds, which led to underrating, potentially because some steps may fall below the minimal threshold (generally around 0.3 g) required to trigger a step count [27].

The limitations of this study included the homogeneity of the horse group and the small sample size. Burla and colleagues failed to detect an influence of horse height on acceleration values, but observed a difference between 'gaited' (such as Icelandic horses) and 'non-gaited' horses [10]. Another limitation refers to the use of accelerometer-generated data to evaluate the device's step frequency performance at the walk rather than continuous videorecording during *stage 6* in the horse walker. However, when accelerometer-generated data were compared with videorecordings of the walk during *stage 3*, the step frequency was shown to be very accurate.

The current study demonstrates that the dual-mode accelerometer can accurately quantify and compare locomotor activity in horses moving at different speeds and gaits, and that positioning on the hindlimb allows for the most accurate results. The step count function can be useful but must be corrected using the activity count when data for different gaits are compared. Further investigations should evaluate more specifically locomotor activity in confined areas, such as small movements in a stall, and test the ability of the accelerometer to detect behavioural activity in horses in the absence of minimal ambulation.

Authors' declaration of interests

No competing interests have been declared.

Ethical animal research

Ethical approval to conduct this study was obtained from the Committee of Animal Experimentation, Bernese Cantonal Veterinary Office, Switzerland (Approval No. BE94/13). All animals belonged to the National Equine Centre (represented by the co-author S. Montavon), from which consent for their participation in the study was obtained.

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Authorship

M. Fries and O. L. Levionnois contributed to all steps in the study, including the experimental design, data collection and analysis and the writing of this paper. S. Montavon contributed to the design of the study and provided logistical support. C. Spadavecchia contributed to the design of the study and to the preparation of the manuscript.

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[e]Systat Software, Inc., San Jose, California, USA.
[f]MedCalc Software BVBA, Ostend, Belgium.

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