Evaluation of Pedometers for Measuring Distance Traveled by Cattle on Two Grazing Systems

JOHN W. WALKER, R.K. HEITSCHMIDT, AND S.L. DOWHOWER

Abstract

The precision and accuracy of pedometers for measuring distance traveled by cattle on production size grazing systems were studied. Pedometer calibration factors were similar among cattle, but varied because of differences in the sensitivity of pedometers to movement and/or the tightness of the case around the animal's leg. Adjusting pedometer readings by their individual calibration factor provided a precise and accurate measure of travel distance. Cattle on a short duration grazing system tended to walk farther, and travel distance was more variable than with animals on a continuous grazing system.

Travel influences the energy requirements of free grazing cattle. The energy cost of travel may increase the maintenance energy requirements of grazing livestock by 10 to 24% compared to stall fed animals (Ribeiro et al. 1977, Havastad and Malecheck 1982). Anderson and Kothmann (1980) and Gammon and Roberts (1980) showed that distance traveled by cattle varied among grazing systems. Thus, animal performance may be influenced because of differences in energy expended for travel in different grazing systems. However, information pertaining to the effect of grazing systems on travel is scarce.

Livestock travel distance has usually been estimated by charting animal movements on paper, which is a laborious and subjective procedure. Pedometers have been investigated as a low cost alternative for measuring travel distance. Powell (1968) evaluated "Suprex" pedometers on sheep and reported that pedometers must be individually calibrated to each animal and that accurate calibration could not be obtained for some animals. Anderson and Kothmann (1977) reported that digital pedometers provided a precise and inexpensive method for monitoring distance traveled by cattle. However, they did not evaluate the accuracy of pedometers and used only 2 animals to estimate precision.

The objective of this series of experiments was to evaluate the reliability of pedometers for estimating distance traveled by cattle on production scale short duration and continuous grazing systems. The study was designed to identify sources of variation associated with both calibration and the measurement of distance traveled by grazing cattle.

Methods and Materials

Five experiments were conducted to test the accuracy and precision of pedometers for measuring distance traveled by cattle. The study was conducted at the Texas Experimental Ranch located in the Rolling Plains Resource Region. The cattle used in this study were mature Hereford × Angus cows, except for Exp. 2 where 3

Hereford cows and 2 Hereford × Simmental steers that had been esophageally fistulated were used and Exp. 5 where a horse was used.

The instruments used in this experiment were "Digi-Meter" pedometers (manufactured by Edge Mark, Japan) and were the same model pedometer evaluated by Anderson and Kothmann (1977). Vertical movement of the pedometer activates a pendulum mechanism that is mechanically linked to a digital readout. The pace length adjustment was standardized among pedometers using a mechanical shaker. The setting was maintained by securing the pace length adjustment screw with silastic (silicon sealant, General Electric, USA).

Pedometers were enclosed in a case constructed of 4.8-mm thick acrylic plastic (Fig. 1). The case was attached around the metacarpus of the foreleg with a 37-mm wide plastic leg band to prevent

Fig. 1. *Pedometer enclosed in a plexiglas case that is attached to a cow's foreleg.*

slippage on the animal's leg. The inside surface of the leg band and case were padded with foam rubber to prevent abrasion.

Calibration factors were calculated by dividing the travel distance measured on the pedometer by the actual distance walked. Animals were walked 1.6 km along a fence to determine the calibration factor. Pedometer readings and the time of reading were recorded daily in Exp. 1 and 2 and at the beginning and end of Exp. 3 and 4. Average daily travel distance was calculated by dividing the difference between the beginning and ending pedometer reading by the individual calibration factor and then adjusting this distance to a 24-hr basis.

Experiment 1—Ten cows were equipped with 1 pedometer on each front leg. The study area was a 39-ha pasture that was part of a 16-pasture short duration grazing cell. Pedometers were calibrated once a day on 3 consecutive days beginning on the first day of the experiment; distance traveled was recorded daily for 2 days. Three cows were not included in the analysis because their pedometers were either lost or broken during the study. Calibration factors and travel data were analyzed for the effect of animals, and pedometers nested within animals (pedometers/animals) with both factors considered as random effects and days considered as replications. Analysis of variance for this and subsequent experiments were performed using the general linear models procedure of statistical analysis system (Helwig and Council 1979).

Experiment 2—Five docile esophageally fistulated animals (3 Hereford cows and 2 Hereford × Simmental steers) were equipped with a pedometer on each leg. The study area was a 6-ha pasture.

Pedometers were calibrated on 2 consecutive days. Calibration was replicated 3 times the first day and 2 times the second day. Pedometer readings were recorded both days. Calibration factors were analyzed for the random effects of animal, pedometer/animal, day, and all two-way interactions. Travel data were analyzed for the random effects of animal and pedometer/animal with days as replicates.

Experiment 3 and 4—These experiments were conducted to evaluate the reliability of pedometers for estimating travel distance in production scale grazing systems. Travel was monitored concurrently in both treatments. Grazing systems studied were short duration (SDG) and continuous grazing (CG). The SDG treatment contained 16 pastures fenced in a cell design on 450 ha and stocked with 125 cows. Pastures ranged in size from 10 to 30 ha. The CG pasture was 242 ha and was stocked with 41 cows. During both experiments, the cattle in the SDG treatment were rotated through the same 5 pastures (two 30-ha pastures and three 10-ha pastures) that were selected previously to monitor other animal and vegetation parameters. Exp. 3 lasted 6 days and Exp. 4 lasted 9 days. The length of the experiments was determined by the time required to rotate through the SDG pastures, which varied in accordance with the growth rate of the vegetation (Voisin 1959).

Ten cows in each treatment were equipped with 1 pedometer on their right foreleg. A different set of cows was used for each experiment. Pedometers were calibrated 2 times before and 2 times after each experiment except for the pedometers on the SDG cattle in Exp. 3, which were calibrated only at the end of the experiment. Pedometers were read at the beginning and end of each experiment as well as between pastures in the SDG treatment. Travel in each pasture was averaged to determine daily travel for the SDG cattle. Calibration factors were analyzed for only for 6 of the CG cattle in Exp. 3 due to incomplete data caused by lost or broken pedometers. Likewise calibration factors were available from 7 and 5 of the SDG and CG cattle, respectively, in Exp. 4. Calibration factors from Exp. 3 were analyzed with a mixed model for the effects of animal (random), time (i.e., beginning vs end, fixed), and their interaction. The analysis of the calibration factors for Exp. 4 was also a mixed model with treatment and animal nested within treatment (animal/treatment) as random effects and time as a fixed effect. The effect of grazing treatment on average daily travel distance was tested using a t-test for independent samples with unequal variances (Snedecor and Cochran 1967).

Observations of cattle locations were used to provide an indication of the accuracy of the pedometer measurements for the CG cattle in Exp. 3 and 4. The location, activity and number of animals in each subherd was recorded hourly during daylight on topographical maps. Travel distance was estimated by measuring the change in each subherd location between successive observations. The only estimate of nighttime travel was the change in location between the last observation before dark and the first observation of the next day. This estimate of travel was used only for the CG cattle because the high density of the SDG cattle rendered such measurements impractical.

Experiment 5.—This experiment was conducted to estimate the effect of an animal's gait on the calibration factor. Because it was considered impractical to keep cattle in any gait other than a walk over the distances necessary to obtain reliable pedometer readings, a horse was used for this experiment. The horse was ridden for 1.6 km at a walk, a trot, and a lope with one pedometer attached around the metacarpal of each front leg. Calibration was only performed once and the data were not analyzed statistically.

Results and Discussion

In Exp. 1 and 2 variation in the calibration factor could not be attributed to differences in animals, day of evaluation, or their interaction (Table 1). The only significant source of variation for pedometer calibration was caused by the pedometer/animal source. There were 2 possible causes for this variation: (1) pedome-

Table 1. Sources of variation, mean squares and associated probabilities of greater F-value in 4 experiments evaluating correction factors for calibrating pedometers on cattle.

Source of variation	d.f.	MS	P
	Experiment 1 (Random Model)		
Animal	6	.099	.57
Pedometer/Animal	7	.117	.00
Residual	28	.020	
	Experiment 2 (Random Model)		
Animal	4	.014	.49
Pedometer/Animal	5	.014	.04
Day	1	.000	.83
Animal × Day	4	.004	.27
Day × pedometer/animal	5	.002	.40
Residual	30	.002	
	Experiment 3 (Mixed Model)		
Animal[1]	5	.445	.06
Time[2]	1	.139	.10
Animal × Time	5	.035	.94
Residual	11	.150	
	Experiment 4 (Mixed Model)		
Treatment[1]	1	.121	.63
Animal/treatment[1]	10	.506	.03
Time[2]	1	.657	.12
Treatment × Time	1	.024	.60
Residual	10	.145	

[1]Random effect
[2]Fixed effect (beginning vs end)

Table 2. Sources of variation, mean squares and associated probabilities of greater F-values for random model analyses of variance of average daily travel distance of cattle in experiments 1 and 2.

	Experiment 1			Experiment 2		
Source of variation	d.f.	MS	P	d.f.	MS	P
Animal	6	2.307	.02	4	2.123	.01
Pedometer/animal	7	0.402	.80	5	0.159	.99
Residual	12	0.766		10	2.983	

ters may have differed in their sensitivity to movement, and/or (2) differences in tightness of the pedometer case around the animal's leg may have caused differences in the amount of free movement. Spurious movement by the pedometer would be registered as additional travel.

The calibration factor was significantly affected by animals and animals/treatment in Exp. 3 and 4, respectively (Table 1). The animal and animal/treatment source represented not only variation in stride among animals but also variation caused by instruments and attachment as discussed for Exp. 1 and 2. Because variation among animals was not significant when instrument and attachment variation were isolated from animal variation in Exp. 1 and 2, the animal variation found in Exp. 3 and 4 was probably caused by differences in the pedometers and/or their attachment. Furthermore, the calibration factor was similar (*P*>.63) between treatments in Exp. 4 (Table 1), which indicated that, on the average, the factor or factors causing significant variation due to animals were equal and represented a random effect on calibration.

The calibration factor was similar (*P*>.83) between consecutive days in Exp. 2 (Table 1), but it increased from the beginning to the end of Exp. 3 (CG cattle only) from 1.83 to 1.96 (*P*<.10) and in Exp. 4 (CG and SDG cattle) from 1.24 to 1.57 (*P*<.12). This increase appeared to be caused by increased free movement of the pedometer due to a change in the tightness of the pedometer attachment around the leg. The change in tightness resulted from compression of the foam rubber padding on the back of the pedometer cases during the evaluation period. Examination of pedometer cases on cattle in the SDG treatment as they rotated between pastures indicated that most of the change in tightness occurred during the first 48 hr of the experiment. Thus for evaluation periods spanning several days, calibrating pedometers at the end of an experiment would be more accurate than calibrating at the beginning of an experiment.

Experiments 1 and 2 showed that daily travel varied among animals but not among pedometers/animals (Table 2). Thus, adjusting the daily change in each pedometer reading by its individual calibration factor removed pedometer variation that occur-

red during calibration and provided a similar estimate of travel distance for each leg. These results are in contrast to those of Anderson and Kothmann (1977), who reported that travel distance varied between treatments but not between animals within a treatment. However, they did not use individual calibration factors to calculate travel distance and the herd size was small, which probably resulted in a cohesive herd that behaved similarly.

Cattle on the SDG treatment walked farther than did cattle on the CG treatment in Exp. 3 and 4 (Table 3). Observations on the

Table 3. The effect of short duration grazing (SDG) and continuous grazing (CG) during Experiments 3 and 4 on daily travel distance estimated from pedometers, and the daily movement of subherds in the CG pasture determined by observation.

	Travel Distance (km • d^{-1} ± S.D.)		
	SDG	CG	
Experiment	Pedometer	Pedometer	Observation
3[a]	10.1 ± 3.31	7.5 ± 1.13	3.8
4[b]	7.1 ± 1.53	6.2 ± .57	3.5

[a]Pedometer estimates of mean daily travel distance differed between treatments (*P*<.07).
[b]Pedometer estimates of mean daily travel distance differed between treatments (*P*<.11).

location and movement of the SDG animals when they were rotated between pastures showed that travel caused by the rotation averaged 1.6 km/rotation. Because of differences between experiments in the length of graze, rotation accounted for 1.3 and .9 km/day in Exp. 3 and 4, respectively. Thus, movement between pastures would account for the additional travel estimated for the SDG cattle in Exp. 4. Gammon and Roberts (1980) reported that travel was greater in rotational grazing systems than continuous grazing systems while Anderson and Kothmann (1980) reported that it was less.

The variance of daily travel distance was greater (*P*<.004 and *P*<.007) in the SDG treatment compared to the CG treatment in Exp. 3 and 4, respectively. Greater variation in travel by the SDG cattle may have resulted from the combined effects of high animal density, proximity between subherds, and social interactions. Animals in the CG treatment tended to stay in cohesive subherds and travel as a group. However, subherds were less distinct in the SDG treatment and the majority of travel appeared to be within and between subherds rather than by the general movement of the subherd. Greater variance of travel distance in the SDG treatment may have resulted from frequent movement by some cows in an attempt to maintain their individual animal space. Leyhausen (1971) postulated that this distance varied as a partial function of social rank. If crowding and social rank caused the individual animal space of only some cows in the SDG treatment to be continually violated, greater variation in daily travel distances would be expected.

The sample size needed to detect a 1-km difference (α=.05, 1-β=.90) in daily travel distance was calculated from a pooled estimate of the within treatment variance (Keppel 1982). These estimates varied from 12 to 3 animals per treatment for Exp. 3 and

4, respectively. About 30% of the pedometers were lost during Exp. 3 and 4. Most of the losses occurred because the pedometer case struck the lower portion of the head gate as the cows exited the squeeze chute. In more recent experiments (unpublished data) we have reduced the loss rate to 15% by removing the squeeze chute and attaching and reading pedometers in the lead up chute.

Evaluation of the accuracy of pedometers for measuring travel distance is difficult because methods involving observation are subjective and thus an absolute measure of this parameter is not easy to obtain. In this study travel distance estimated with pedometers was compared to the general daytime movement of subherds (which were being monitored as part of another study) to determine if pedometer estimates of travel distance were reasonable. Travel distance based on the movement of subherds in the CG treatment was less than the distance measured by pedometers. Subherd movement accounted for 51% and 58% of the travel recorded by pedometers during Exp. 3 and 4, respectively (Table 3). The observation data should have underestimated actual travel distance because it did not account for animal movement within a subherd, or nighttime movement of subherds even if cattle movement at night is limited (Johnstone-Wallace and Kennedy 1944, Dwyer 1961).

Pedometer estimates of travel distance may also be biased if the calibration factor varies because of the type of activity or gait that is associated with movement, since a pedometer will register any leg movement as a step even if it is not associated with walking. Experiment 5 indicated that the calibration factor generally varied less than 10% between a walk, a trot, and a lope (Table 4). The low

Table 4. Calibration factors (pedometer measurement ÷ actual distance traveled) of a horse traveling at different gaits.

Leg	Gait		
	Walk	Trot	Lope
Left	2.4	2.5	2.3
Right	2.0	2.1	1.4

calibration factor for the right pedometer at a lope was probably caused by the effect of rather severe concussion associated with this gait on the sensitivity of the pedometer. Activity that results in leg movement being registered on the pedometer when cattle are presumably standing idle may represent an expenditure similar to walking. This type of minor activity may not be accounted for by observation and the recording of it by pedometers may be considered an advantage for determining energy budgets of grazing cattle.

Conclusions

Because the differences between pedometer estimates of travel distance and the distance traveled by subherds was not excessive and was in the expected direction, and because calibration factors for different gaits were similar, we conclude that pedometers estimate travel distance with relatively high degree of accuracy when properly calibrated. It appears that the major problem with this technique is mechanical malfunction of the pedometers and loss of instruments during experiments. Thus the use of 2 pedometers per animal would be desirable to avoid losing data because of lost or broken pedometers. Although calibration factors may vary slightly between consecutive calibrations on the same day, and between the beginning and the ending of an experiment, we believe that calibrating twice at the end of an experiment provides a reasonable compromise between accuracy and the amount of effort used for calibration.

Literature Cited

Anderson, D.M., and M.M. Kothmann. 1977. Monitoring animal travel with digital pedometers. J. Range Manage. 30:316-317.

Anderson, D.M., and M.M. Kothmann. 1980. Relationship of distance traveled with diet and weather of Hereford heifers. J. Range Manage. 33:217-220.

Dwyer, D.D. 1961. Activities and grazing preferences of cows with calves in northern Osage County, Oklahoma. Okla. Agr. Exp. Sta. Bull. B-588.

Gammon, D.M., and B.R. Roberts. 1980. Grazing behavior of cattle during continuous and rotational grazing of the Matopos sandveld of Zimbabwe. Zimbabwe J. Agr. Res. 18:13-27.

Helwig, J.T., and K.A. Council. 1979. SAS User's Guide. SAS Institute Inc., Raleigh.

Havastad, K.M., and J.C. Malechek. 1982. Energy expenditure by heifers grazing crested wheatgrass of diminishing availability. J. Range Manage. 35:447-450.

Johnstone-Wallace, D.B., and K. Kennedy. 1944. Grazing management practices and their relationship to the behavior and grazing habits of cattle. J. Agr. Sci. 34:191-197.

Keppel, G. 1982. Design and analysis a researcher's handbook. p. 70-73. Prentice-Hall, Inc., New Jersey.

Leyhausen, P. 1971. Dominance and territoriality as complemented in mammalian's social structure. p. 22-23. In: A.H. Esser (Ed.) Behavior and Environment. The Use of Space by Animals and Man. Plenum Press, New York.

Powell, T.L. 1968. Pedometer measurements of the distance walked by grazing sheep in relation to weather. J. Brit. Grassld. Soc. 23:98-102.

Ribeiro, J.M. de C.R., J.M. Brockway, and A.J.E. Webster. 1977. A note on the energy cost of walking in cattle. Anim. Prod. 25:107-110.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical Methods (6th Ed.). p. 114-117. Iowa State Univ. Press, Ames.

Voisin, A. 1959. Grass Productivity. Philosophical Library Inc., New York.