Implications for daily body weight data on beef cattle grazing extensive rangelands

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Abstract

Estimating performance of beef cattle grazing on extensive rangeland systems is difficult due to labor constraints and stress on animals. Average daily gain (ADG) is an important metric to measure individual animal growth and efficiency, and daily estimates of body weight can help inform management decisions such as supplementation strategy or culling. SmartScale™ (C-Lock Inc., Rapid City, SD) is a relatively new technology placed in front of existing water tanks that captures front-end weight and RFID tag information while animals are drinking. Though front-end weights greatly increase temporal resolution of individual weight data on animals grazing extensive pastures, no study has quantified the relationship between partial body weight and full body weight across a range of cattle classes. Data collected in 2020-2022 at the Cottonwood Field Station near Philip, SD compared full body weight to partial body weight across mature cows, bred heifers, weaned calves, and yearling steers. Linear regression analysis found a significant relationship ($P < 0.001$) between partial body weight and full body weight across all classes of cattle ($R^2 = 0.96$), demonstrating the precision of this technology to measure animal body weight in pasture. In addition, season-long SmartScale™ data was used to present a case study on the application for selecting replacement heifers based on quantile regression. Overall, the ability to measure daily body weights of cattle grazing extensive systems can identify low-performing animals, greatly improve management efficiency, and quantify animal performance.

Keywords: rangelands, precision weighing, beef cattle

Introduction

Gathering repeated body weights of beef cattle raised within extensive production systems is difficult due to labor constraints and stress on animals. Animals raised within extensive systems are often less accustomed to handling, resulting in increased cortisol levels and displays of aggressive behavior when processed in handling facilities (Grandin, 1997). Increased stress levels can negatively impact cattle reproductive potential, growth performance, and health (Grandin et al., 1998). As a result, livestock within extensive systems are often weighed infrequently. Average daily gain (ADG) is an important metric to measure animal performance and efficiency. Increased temporal resolution of weight data could help inform management decisions such as supplementation needs or animal selection/culling. Conventional weighing methods recorded within livestock handling chutes can be influenced by time of weighing, temperature, handling procedures, and ruminal fill (Watson et al., 2013). This can lead to large variations in individual animal body weights and subsequently influence performance metric estimates (e.g., ADG). Advances in technology have sought alternative methods for estimating live weight of cattle, potentially replacing traditional chute weights as the standard for measuring body mass. These methods include walk over weigh scales for in pasture measurements (Dickinson et al., 2013) and biometric and morphometric measurements derived from computer vision camera systems (Wang et al., 2021). Partial body weights (Pbw) have been used to predict full body weight (Fbw) and ADG within feedlot cattle using GrowSafe™ systems (MacNeil et al., 2021). SmartScale™ (C-Lock Inc., Rapid City, SD) is a relatively new technology placed in front of existing water tanks that captures Pbw and RFID tag information while animals are drinking. However, no study has quantified the relationship between Pbw derived from SmartScale™ technology and Fbw weight across a range of animal classes. Additionally, SmartScale™ technology deployed on pasture can greatly increase the temporal resolution of animal weight. Quantile regression (QR) is a statistical technique that allows for modeling different quantiles of the distribution of the dependent variable (Koenker and Bassett, 1978). Quantile regression has been used to evaluate growth curves in pigs to correlate feed efficiency and genetics to ADG (Nascimento et al., 2018); however, no examples exist using this technique on rangeland beef cattle. The objective of this study was to 1) assess the accuracy and repeatability of Pbw derived from SmartScale™ technology to measure live animal Fbw and 2) demonstrate the applicability of daily weights for estimating different performance quantiles for beef cattle grazing rangelands.

Materials and methods

Study site

Research for this study occurred at the South Dakota State University Cottonwood Field Station (CFS), which is in the Northern Great Plains mixed-grass prairie (43.989107 N, -101.857228 E). Elevation at the station ranges from 710 m to 784 m. Climate is characterized as an arid cold steppe (Beck et al., 2018). Long-term average (1981-2010) annual precipitation for the area is 432 mm (NOAA, 2022). The field station has two primary livestock handling facilities. The main working facility is located adjacent to a drylot and utilizes a Silencer™ (Stapleton, NE) hydraulic squeeze chute mounted on load cells and bars (Tru-Test, Mineral Wells, TX). The secondary working facility is located within summer grazing pastures and utilizes a portable For-Most™ (Hawarden, IA) squeeze chute with Tru-Test load bars. In addition, the station utilizes eight SmartScales™ that are moved between existing water sources within the dry lot and pasture. Each SmartScale™ is equipped with an RFID tag reader and records individual animal Pbw (front-end) while animals are drinking. Data from the SmartScale™ is accessed from the cloud via an automatic programming interface (API) in program R.

Experiment 1

An experiment was conducted to estimate the accuracy and repeatability of conventional weighing versus SmartScale™ weighing. Ten mature, non-lactating cows Fbw of were measured on the Silencer™ chute at the CFS on 14-day intervals for a period of 106 days. Seven weigh dates were recorded between 1 February 2022 and 18 May 2022. Following Fbw collection, cows were turned into a drylot with SmartScales™ placed in front of waterers. Only SmartScale™ weights recorded on the same day as the whole body weight were used. If multiple SmartScale™ weights occurred on the same day, the daily average weight for each individual animal was used for calibration. A total of 59 Fbw and corresponding Pbw were used for the analysis. A linear regression model was fit using program R with Fbw as the response variable and Pbw as the predictor variable. Cook's distance method was used to identify any outliers in the dataset with values four times the means. One data point was identified as an outlier and removed from the dataset. A significant relationship between Fbw and Pbw was determined at an alpha of less than 0.05. In addition, tests for heteroscedasticity were conducted to check for unequal distribution of residuals.

Experiment 2

A second experiment was conducted to estimate the accuracy of Pbw to predict Fbw across a range of weights and classes of cattle. Whole body weights were recorded across five classes of cattle: bred heifers (n=34), non-lactating mature cows (n=59, data from experiment 1), weaned calves (n=34), yearling heifers (n=120), and yearling steers (n=119). For bred heifers, mature cows, weaned calves, and yearling heifers Fbw were measured at the CFS primary working facilities on the Silencer™ chute. For the yearling steers, Fbw was recorded on the For-Most™ squeeze chute at the secondary working facilities. All data were recorded between 20 November 2021 and 10 June 2022. For the weaned calves and mature cows, SmartScale™

weights were obtained in drylot conditions. For the bred heifers, yearling heifers, and yearling steers, SmartScale^{TM} weights were obtained on pasture. Only SmartScale^{TM} weights recorded on the same day as the Fbw were used for analysis. With the exception of the mature cow weight data described above, all animal weights were recorded once. A total of 366 Fbw and corresponding Pbw were used for the analysis. Six outliers were identified and removed from the dataset using the Cook's distance method described above. Outliers removed were from the bred heifer (n=4) class, the mature cow (n=1) class, and the yearling steer (n=1) class. A validation set approach was used by randomly splitting the data into a 70% training, 30% testing dataset. A linear model was fit to the training dataset and used to predict the Fbw on the test dataset. Root mean square error (RMSE) and linear model coefficients were used to assess the accuracy of predicted versus observed weights on the test dataset.

Experiment 3

In this example, SmartScales^{TM} were used to collect daily heifer weight data on 60 individuals grazing dormant winter range from November 2021 to May 2022. Heifers were supplemented with 2.27 kg/hd/d of pelleted dried distiller's grains (DDGS) delivered using either a precision feeder (SmartFeed^{TM}, C-Lock Inc., Rapid City, SD) or conventionally fed in a feed bunk. SmartScale^{TM} weights were converted to Fbw using a linear equation described above; a three-day rolling average was then applied to each individual animal's weight over the duration of the trial to reduce daily variance. A QR model was used to estimate ADG for the 10, 25, 50, 75, and 90th percentile groups with animal body weight as the dependent variable and day of trial as the independent variable.

Results

Experiment 1

There was a significant relationship ($P < 0.001$) between Pbw measured on the SmartScale^{TM} and Fbw measured in the chute for mature cows (Figure 1). The adjusted r^2 value of 0.91 indicates that the regression equation explained much of the variation between whole body weight measured on the chute and partial front-end weights obtained by the automated scale.

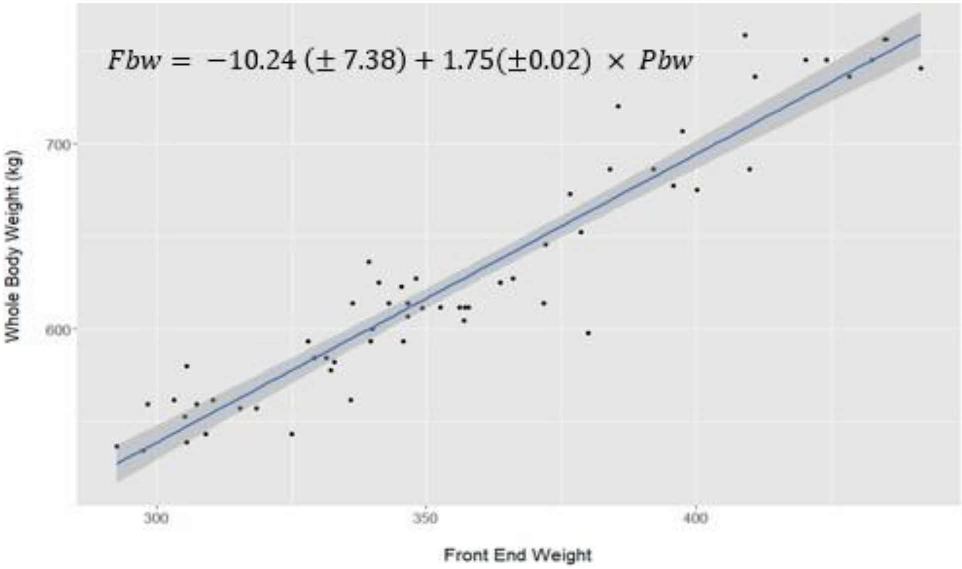

Figure 1: Comparison of front-end weight to whole body weight for mature cows measured using SmartScale^{TM} technology (C-Lock Inc., Rapid City, SD) and a silencer hydraulic squeeze chute.

Experiment 2

There was a significant relationship ($P < 0.001$) between Pbw measured on the SmartScale™ and Fbw measured in the chute for all classes of animals. The regression equation from the training data set ($Fbw = -10.89 + 1.75 \times Pbw$) was applied to the test dataset to estimate predicted versus observed body weight (Figure 2). The adjusted r^2 value was 0.96 between predicted and observed Fbw with a slope of 1 and the intercept not significantly different from 0 ($P = 0.8$). The RMSE between observed and predicted Fbw was 21.4.

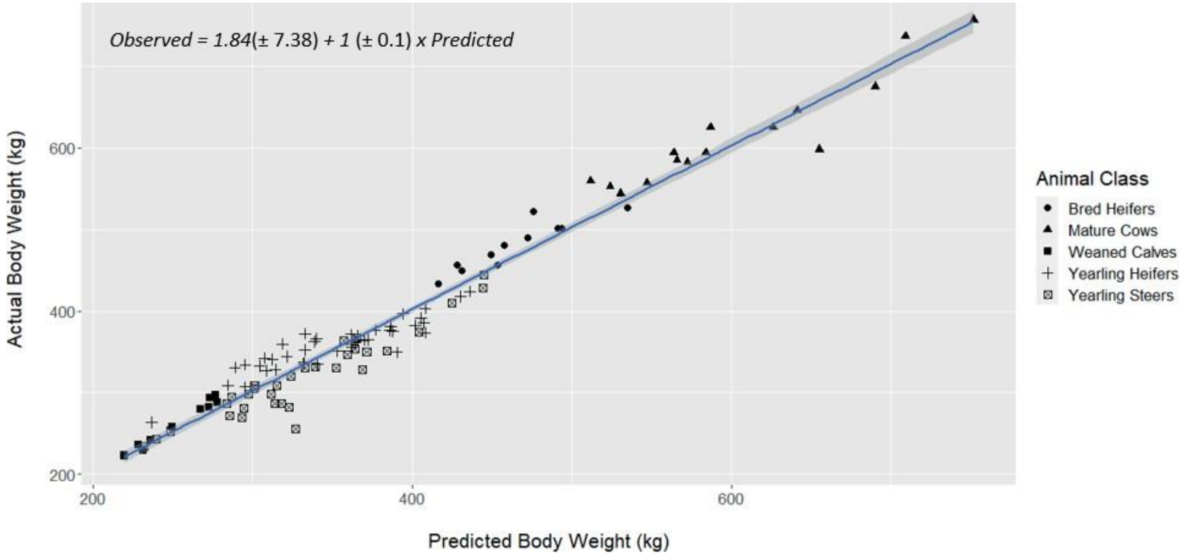

Figure 2: Predicted body weight versus observed body weight for all animal classes measured at the Cottonwood Field Station in South Dakota.

Experiment 3

Model coefficients from the QR can be found for each quantile group in Table 1. There was a 0.15 kg difference in ADG between the top 90% and the bottom 10%. Over 200 days this would result in a difference of 30 kg of gain between these animals. In addition, intercept differences between the top and bottom quantiles indicate a 36 kg difference between starting body weight for the different quantile groups.

Table 1: Quantile regression (QR) analysis coefficients for each quantile group. The intercept represents the beginning weight (e.g., weaning weight in kg) for each group and the slope is an estimate of average daily gain in kg/hd/d.

Coefficient	Quantiles				
	10%	25%	50%	75%	90%
Intercept	186	190	203	215	222
Slope	0.76	0.82	0.84	0.87	0.91

Discussion

Implications for range beef cattle

Results demonstrate a strong correlation between Pbw of cattle and Fbw across a range of different animal classes and weighing conditions. These results are consistent with previous research that has reported coefficients of determination between 0.96-0.97 for Pbw versus Fbw of cattle in feedlots (Kolath et al., 2007; Benfield et al., 2017). Additionally, MacNair et al. (2021) found the coefficient of determination of Pbw versus predicted Fbw across 33 groups of cattle to range from 0.86 to 0.99. Slope estimates from our study across all classes of animals was 1.75 × Pbw weight. This differed slightly from results reported by Benfield et al. (2017), who indicated that Fbw can be estimated as 1.677 × Pbw across all sexes and breed types of cattle. Difference in the regression slopes may be due to differences in technology used (GrowSafe™ vs. SmartScales™) or differences between the conditions in which animals were weighed (feedlot vs. pasture). However, our results are consistent with previous literature that Pbw can provide consistent and accurate estimates of Fbw of cattle. For precision weighing technology, the future development of a centralized repository for Fbw and Pbw data sets could help refine front-end scale calibration across a range of technologies, animal classes, and breeds. Frequent weighing of beef cattle grazing extensive rangelands using conventional methods may potentially underestimate rates of gain and exaggerate rates of loss due to stress on handling animals (Martin et al., 1967). Factors such as the time of day, weather conditions, and rumen fill can impact body weight of beef cattle (Koch et al., 1958; Heitschmidt, 1982). This effect can be magnified for studies measuring performance across multiple pastures on extensive rangeland studies, where the time required herding animals to a centralized working facility can vary greatly. The rate of weight loss is approximately 1% every 3 hr after an initial 3-hour loss of 3.5% of body weight, and early morning weights of range cows have been shown to be approximately 2.5% less than late morning weights (Heitschmidt, 1982). Thus, the timing in which pastures have been herded and amount of time animals must wait in corrals to be weighed, can significantly impact measurements of body weight and subsequent estimates of performance. While limit feeding protocols and multiple day weights may reduce the influence of gut fill on animal weight, consistency in handling cattle when weighing may be more important to reducing variability in animal weights than limiting intake (Watson et al., 2013). Additionally, weighing animals over multiple days can increase precision in cattle weights (Stock et al., 1983). One major benefit to utilizing precision weighing technology for measuring animal weights is the ability to get multiple weights per day under a variety of conditions, which can be averaged or smoothed using 2-3 day rolling averages, potentially providing a more precise and consistent method for estimating beef cattle weights. In addition, passive weighing of animals on pasture will likely reduce the influence of stress and shrink on animal nutritional status and performance. In total, 366 weights were used in our analysis, of which six were identified as outliers in the dataset representing 1.6% of all measurements. Errors from precision technology are likely to occur, especially due to the large volume of measurements collected. These errors may potentially be due to animals not standing on the scale properly, which may result in an underestimate of weight or multiple animals standing on the scale at once resulting in overestimates. Although our results demonstrate that SmartScale™ technology can provide accurate and repeatable estimates of Fbw for a range of animal classes, it is critical that there are processes to automatically filter and clean erroneous weight data in the development of precision weighing technology for real-time information.

Quantile regression case study

Results from the QR analysis illustrates one potential application for analyzing daily weight data on beef cattle grazing extensive rangelands. In addition to tracking herd level averages, data from this technology can be used to benchmark individual growth rates of heifers to their peers (Figure 3). This can be used to infer differences in feed efficiency or genetics across animals and factor into management decisions such as allocating animals to different tracts (e.g., cull, replacement, or stocker). For example, a common management practice for producers developing heifers is to reach 60-65% of mature body weight at time of breeding as yearlings (Larson, 2000). Lower quantile performing cattle may need to be managed differently to adjust performance or could be culled. Real-time weight data on animals grazing extensive systems may be able to identify underperformers earlier in the production phase to reduce feed cost on underproductive animals. Likewise, over conditioned heifers at time of first breeding may require a higher level of dietary energy to maintain body condition during breeding and gestation (Funston et al., 2012). Individuals within the top 90-95 percentile may be able to be identified earlier in the production process to slow growth or moved into a different production tract (stocker/feeder). The ability to track beef cattle performance on rangeland using precision weighing technology provides new opportunities to improve efficiencies in the ways animals are fed, supplemented, and managed.

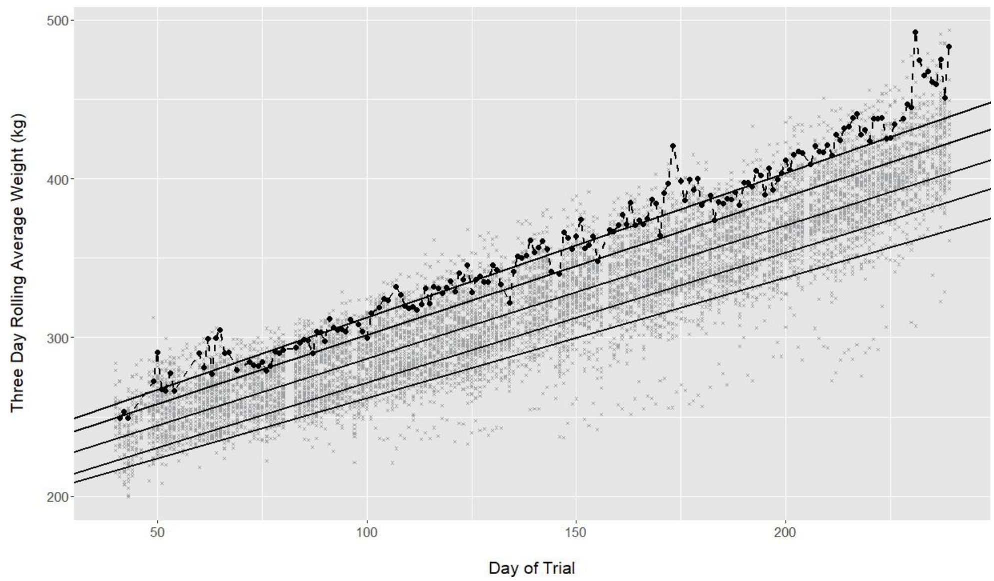

Figure 3: Quantile regression (QR) plot for heifer growth. The black lines represent the 10, 25, 50, 75, and 90 percentiles for growth over the trial. Grey dots represent the three-day rolling average for all animal weights. The black dotted line is one individual animal's weight over the course of the trial. Daily weights were derived from SmartScales^{TM}.

Conclusions

Novel technologies like precision weighing can provide unprecedented insight into beef cattle performance that isn't possible with infrequent weighing of animals. Validation of Pbw versus measured chute weight across a range of animal classes is essential for the adoption of this technology. The objectives of this study were to demonstrate the relationship between Pbw measured using SmartScales^{TM} and Fbw and to provide an example on how this precision data can be applied to inform management decisions. Further, challenges with conventional weighing of rangeland beef cattle highlight the implicit biases of tradition weighing (e.g., two day scale weights) variation and may provide a future direction for more precise weight collection through passive methods like front-end weight. Future research directions should include methodologies to automate processing and cleaning of real-time data to remove erroneous data points.

Acknowledgments

This research was made possible with an equipment grant from C-Lock Inc. (Rapid City, SD), donation of DDGS pellets from POET Nutrition (Sioux Falls, SD), USDA Hatch grant (#SD00H724-21) and the South Dakota State University Agriculture Experimental Station.

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