Evaluation of Sow Caliper for body condition measurement of gestating sows

Yuzhi Li, PhD; Shiquan Cui, PhD; Samuel K. Baidoo, PhD; Lee J. Johnston, PhD

Summary

Objectives: To evaluate correlation between Sow Caliper measurement and backfat depth (BFD), and to determine the ideal caliper measurement that predicts optimal BFD prefarrowing to support performance of lactating sows.

Materials and methods: Multiparous sows (n = 928, Parity 1-9) were group housed in pens from day 35 to 109 of gestation. Caliper measurements, BFD, visual body condition scores (BCS), and body weight were recorded upon sows' entry and exit of gestation pens. Subsequent farrowing performance was recorded. Caliper measurements were classified into five categories: category 1 = 4.0 to 8.0 units, category 2 = 8.5 to 10.0 units, category 3 = 10.5 to 12.0 units, category 4 = 12.5 to 14.0 units, and category 5 = 14.5 to 18.0 units.

Results: Caliper measurement was correlated positively with BFD (r = 0.71-0.75; P < .001) and BCS (r = 0.67-0.75; P < .001) on days 35 and 109 of gestation. Based on sow performance over one reproduction cycle and BFD recommendations, caliper category 4 on day 109 of gestation was deemed ideal for prefarrowing sows. The estimated lower and upper limits of BFD for prefarrowing sows in caliper category 4 were 15.6 and 18.0 mm, respectively. Caliper measurements explained about 55% of variation in BFD of gestating sows prefarrowing.

Implications: The Sow Caliper can be used to evaluate body condition of gestating sows. To maintain body condition and reproductive performance, caliper measurements of 12.5 to 14.0 units are recommended for prefarrowing sows across parities, excluding gilts.

Keywords: swine, backfat, body condition score, performance, Sow Caliper

Received: September 18, 2020
Accepted: March 17, 2021

Resumen - Evaluación del Caliper para Hembras para medir la condición corporal de cerdas gestantes

Objetivos: Evaluar la correlación entre la medición del Caliper para Hembras y la profundidad de la grasa dorsal (BFD), y determinar la medición ideal del caliper que predice la BFD óptima antes del parto para respaldar el rendimiento de las cerdas lactantes.

Materiales y métodos: Se alojaron en corrales grupos cerdas multíparas (n = 928, paridad 1-9) desde el día 35 al 109 de gestación. Las medidas del Caliper, la BFD, el puntaje de condición corporal visual (BCS) y el peso corporal se registraron cuando las cerdas entraron y salieron de los corrales de gestación. Se registró el rendimiento del siguiente parto. Las medidas del Caliper se clasificaron en cinco categorías: categoría 1 = 4.0 a 8.0 unidades, categoría 2 = 8.5 a 10.0 unidades, categoría 3 = 10.5 a 12.0 unidades, categoría 4 = 12.5 a 14.0 unidades y categoría 5 = 14.5 a 18.0 unidades.

Resultados: La medición del Caliper se correlacionó positivamente con la BFD (r = 0.71-0.75; P < .001) y la BCS (r = 0.67-0.75; P < .001) en los días 35 y 109 de gestación. Según el rendimiento de la cerda durante un ciclo reproductivo y las recomendaciones de la BFD, la categoría 4 del caliper en el día 109 de gestación se consideró ideal para las cerdas en preparto.

Los límites inferior y superior estimados de la BFD para cerdas preparto en la categoría 4 del Caliper fueron 15.6 y 18.0 mm, respectivamente. Las mediciones del Caliper explicaron aproximadamente el 55% de la variación en la BFD de las cerdas gestantes antes del parto.

Implicacións: El Caliper para Hembras se puede utilizar para evaluar la condición corporal de las cerdas gestantes. Para mantener la condición corporal y el desempeño reproductivo, se recomiendan medidas de caliper de 12.5 a 14.0 unidades para cerdas antes del parto en todas las paridades, excluidas las primerizas.

Résumé - Évaluation du calibre pour truie pour la mesure de l'état corporel des truies gestantes

Objectifs: Évaluer la corrélation entre la mesure du calibre pour truie et la profondeur du gras dorsal (BFD), et déterminer la mesure idéale du calibre qui prédit le BFD optimal pré-mise bas pour soutenir la performance des truies en lactation.

Matériels et méthodes: Des truies multipares (n = 928, parité 1 à 9) ont été hébergées en groupe dans des enclos du 35e au 109e jour de gestation. Les mesures du calibre, du BFD, les scores de l'état corporel visuel (BCS) et le poids corporel ont été enregistrés à l'entrée et à la sortie des truies des enclos de gestation. Les performances de mise bas ultérieures ont

YL, SC, LJJ: West Central Research and Outreach Center, University of Minnesota, Morris, Minnesota.

SKB: Southern Research and Outreach Center, University of Minnesota, Waseca, Minnesota.

SC is now with College of Animal Science and Technologies, Northeast Agricultural University, Harbin, Heilongjiang Province, P. R. China.

Corresponding author: Dr Yuzhi Li, 46352 State Hwy 329, Morris, MN 56267; Tel: 320-589-1711; Email: **yuzhili@umn.edu**.

This article is available online at **http://www.aasv.org/shap.html**.

Li Y, Cui S, Baidoo SK, Johnston LJ. Evaluation of Sow Caliper for body condition measurement of gestating sows. *J Swine Health Prod*. 2021;29(5):245-252. https://doi.org/10.54846/jshap/1232

été enregistrées. Les mesures du calibre ont été classées en cinq catégories: catégorie 1 = 4.0 à 8.0 unités, catégorie 2 = 8.5 à 10.0 unités, catégorie 3 = 10.5 à 12.0 unités, catégorie 4 = 12.5 à 14.0 unités et catégorie 5 = 14.5 à 18.0 unités.

Résultats: La mesure du calibre était corrélée positivement avec le BFD (r = 0.71-0.75; P < .001) et le BCS (r = 0.67-0.75; P < .001) aux jours 35 et 109 de la gestation. Sur la base des performances des truies sur un cycle de reproduction et les recommandations de BFD, la catégorie de calibre 4 au jour 109 de la gestation a été jugée idéale pour les truies avant la mise bas. Les limites inférieures et supérieures estimées de BFD pour les truies avant la mise bas de la catégorie 4 étaient respectivement de 15.6 et 18.0 mm. Les mesures du calibre pour truie expliquent environ 55% de la variation de BFD des truies gestantes avant la mise bas.

Implications: Le calibre pour truies peut être utilisé pour évaluer l'état corporel des truies gestantes. Pour maintenir la condition corporelle et les performances de reproduction, des mesures de 12.5 à 14.0 unités sont recommandées pour les truies avant la mise bas dans toutes les parités, à l'exclusion des cochettes.

Sows are managed to maintain body condition which optimizes welfare, performance, and longevity.[1] Sows that are too thin or too fat are usually removed from the breeding herd sooner than desired due to either compromised animal welfare or poor reproductive performance. Thin sows may farrow and wean lighter weight pigs due to insufficient nutrients for litter development and milk production, and have prolonged wean-to-estrus intervals due to suppressed hormone levels.[2,3] Sows that suffer from severe malnutrition with poor body condition experience compromised welfare and should be euthanized.[4] On the other hand, excessive body condition of sows during gestation can negatively affect litter size, litter weight, and litter uniformity at parturition.[1,3,5] In addition, fat sows are vulnerable to lameness that compromises animal welfare and reproductive performance.[6]

Body condition is important to sow welfare and performance, but it is not easy to measure accurately. Traditionally, sow condition has been evaluated by visual scoring, which is subject to human errors resulting in low repeatability (agreement among measurements by the same observer) and reproducibility (agreement among observers).[1,7,8] Measuring backfat depth (BFD) is another way to evaluate sow condition, which is more reproducible than visual scoring,[1,8,9] but requires equipment and added labor. Previous work[8,9] demonstrated that BFD is poorly or moderately correlated (r = 0.30-0.60) with visual body condition score (BCS), suggesting that visual scoring is not a reliable measurement of body condition for sows. Regardless, visual scoring is still used widely in the swine industry due to its simplicity and no need for specialized equipment.

Recently the Sow Caliper, a simple mechanical tool, has been used by pork producers across the world to measure body condition of sows.[10,11] The Sow Caliper is supposed to measure both backfat and muscle mass which dictate body condition.[10] Compared to visual condition scores, caliper measurements are more objective, which may result in a better measurement of body condition. However, limited research has been conducted to evaluate how Sow Caliper measurements are related with BFD and performance of sows. This study was conducted to evaluate the correlation between Sow Caliper measurement and BFD. In addition, the optimal range of Sow Caliper measurements prefarrowing for sows to maintain reproductive performance and BFD was assessed.

Animal care and use

The University of Minnesota Institutional Animal Care and Use Committee reviewed and approved the experimental protocol for this project (IACUC No. 1406-31590A).

Materials and methods

Animals, housing, and management

This study was part of a larger project conducted at the University of Minnesota's Southern Research and Outreach Center in Waseca, Minnesota using 928 pregnant sows from 20 contemporary breeding groups. Details about animal management in this study have been described previously.[12] During data collection, the sow herd did not have major health issues and all sows enrolled in the study were deemed healthy by visual assessment.

Briefly, gestating sows (Large White × Danish Landrace; TOPIGS Inc; Parity 1-9) were housed in pens (42-51 sows/pen) with an electronic sow feeder (ESF) on fully slatted floors from day 35 of gestation. Sows remained in their designated ESF pens and were managed as static groups[13] until day 109 of gestation. Throughout the gestation period, each sow was provided 2.25 kg of a gestation diet daily, which was adjusted biweekly according to BCS of the sow to try to achieve a visual condition score of 3 at parturition.[14] For sows with body condition below or above the desired score, 227 g feed per day was added or reduced, with the maximal daily feed addition or reduction of 454 g. On day 109 of gestation, sows were moved to confinement farrowing accommodations with *ad libitum* access to water and fed 2.25 kg daily of a lactation diet in a dry feeder. After parturition, sows were allowed *ad libitum* access to the lactation diet and water throughout lactation. To keep the feed fresh, sows were fed twice daily to their appetite, and feed intake was monitored.

Piglets were crossfostered within 24 hours after birth to achieve a litter size between 11 and 13 piglets. The mean (SD) piglet weaning age was 18 (1.5) days. All diets were corn-soybean meal based in mash form and were formulated to meet or exceed nutrient requirements of the National Research Council for gestating and lactating sows.[15] Room temperature was controlled by a heating system and exhaust fans and maintained as close as possible to thermoneutral conditions for sows in both gestation and lactation accommodations. Lights in each room were on for 10 hours daily starting from 6 AM in both gestation and lactation accommodations.

Data collection

Body weight, BFD, BCS, and caliper measurement. Individual body weight (BW) and BFD were recorded for sows on days 35 and 109 of gestation, and on the day of weaning. Backfat depth was measured at the last rib, 6 to 7 cm off the midline on both left and right sides[16] using an ultrasonic scanner (Lean-meater, Renco Corp) by the same trained employee throughout the study. Visual assessment of BCS and caliper measurement were recorded on days 35 and 109 of gestation after measurement of BFD. The method for visual assessment of BCS followed those of Coffey et al[14] using a scoring system of 1 to 5: score 1 = emaciated; score 2 = thin; score 3 = ideal; score 4 = fat; and score 5 = obese, with 0.5 as a minimum score.[8]

The Sow Caliper used in this study has been described by Knauer and Baitinger.[10] The arms of the caliper were 3.5 cm long, and the maximal distance between the two arms was 26.0 cm. The range of caliper measurement was between 1.0 and 30.0 units, with each unit equal to 5.0 mm. The caliper measurement was taken at the same location where BFD was measured.[10] Both visual assessment of BCS and the caliper measurement were conducted by the same researcher throughout the study to avoid discrepancy among researchers. The researcher recorded BCS before taking the caliper measurement, and did not have any knowledge about BFD of the sow at the time of BCS assessment. Measurements of BFD using the ultrasonic scanner and body condition using the caliper were carried out in gestation stalls the day before sows entered ESF pens and in farrowing stalls on the day that sows entered farrowing rooms and at weaning.

Reproductive performance and lactation feed intake. Standard production data including farrowing rate (number of sows farrowed/number of sows assigned to the study × 100), total and live litter size, stillborn pigs per litter, litter size after crossfostering, litter size at weaning, and litter weight at birth and at weaning were collected for all sows. Sows that farrowed and weaned a litter and were mated within one week after weaning were considered to have completed the study. Completion rate (number of sows completing the study/number of sows assigned to the study × 100) was recorded. Feed added to each feeder was weighed and recorded daily from the day of farrowing to the day of weaning. Average feed intake during lactation was calculated for each sow by dividing the total feed provided by the number of days between farrowing and weaning.

Data analysis

Data were analyzed using the SAS software version 9.4 (SAS Institute Inc). The Correlation procedure with Spearman coefficient was used to analyze correlation of caliper measurement with BFD, BCS, and BW for days 35 and 109 of gestation separately. The Regression procedure was performed to predict BFD using caliper measurements for days 35 and 109 of gestation separately, with a quadratic regression based on goodness of fit for each statistical model.

To evaluate the optimal caliper range for BFD and sow performance, caliper measurements were classified arbitrarily into five categories based on caliper measurements in this study. Caliper measurements were classified as: category 1 = 4.0 to 8.0 units; category 2 = 8.5 to 10.0 units; category 3 = 10.5 to 12.0 units; category 4 = 12.5 to 14.0 units; and category 5 = 14.5 to 18.0 units. Descriptive data for BFD and BCS for each caliper category were summarized for days 35 and 109 using the Univariate procedure and are presented in box whisker plots. Sow caliper category on day 109 was used to evaluate effects of caliper category prefarrowing on sow reproductive performance.

The FREQ procedure with Chi-square test was used to analyze farrowing rate and completion rate. Data were tested for normal distribution using the Univariate procedure. The Glimmix procedure was used to analyze BFD, BCS, and litter size with the Gaussian, Poisson, or negative binomial regression distribution to fit the data. The Mixed procedure was used to analyze the data of sow feed intake during lactation, sow weight, and litter weight.

Sow parity was classified into 4 categories: parities 1 and 2; parities 3 and 4; parities 5 and 6; and parities 7 to 9. All models include caliper category, parity classification, and their interaction as fixed effects, pen as a random effect, and sow as the experimental unit. Differences among means were tested by the Tukey test adjusted for multiple comparisons. Significant differences were identified at $P < .05$ and trends at $P < .10$. Data are reported as least squares means (SE).

Results

Caliper measurements, BFD, BCS, and BW on day 35 of gestation were recorded for 898 of 928 sows. Thirty sows with missing caliper measurements were excluded from data on day 35 of gestation. On day 109 of gestation, the same measurements were recorded for 871 sows. Fifty-seven sows were culled due to health or animal welfare problems or failed pregnancy between days 35 and 109 of gestation and were excluded from data collection on day 109 of gestation.

Caliper measurement, BFD, BCS, and BW on days 35 and 109 of gestation

Descriptive data. Medians of BFD increased with caliper category on days 35 (Figure 1A) and 109 (Figure 1B) of gestation. Within each caliper category, BFD varied about 10.0 to 15.0 mm from the minimum to the maximum for both days. Fifty percent (25 to 75 percentile) of sows in caliper category 4 had BFD between 14.5 and 20.0 mm on day 109 of gestation, which is close to the recommended range for BFD.[8,16,17] Similar to BFD, BCS medians increased with caliper category on days 35 (Figure 2A) and 109 (Figure 2B) of gestation. A wide range of BCS was observed within each caliper category for day 35 of gestation. For sows in caliper categories 2, 3, and 5, BCS varied from the minimum 1.5 to the maximum 4.5 on that day. On day 109 of gestation, 50% of sows in caliper category 4 had BCS between 3 and 4.

Correlations and predicting BFD from caliper measurement. Caliper measurement was correlated positively with BFD, BCS, and BW on days 35 and 109 of gestation ($P < .001$ for all coefficients; Table 1). Spearmen correlation coefficients indicate strong correlations between caliper measurement and BFD for both days. Similarly, strong positive correlations between caliper measurement and BCS were observed for days 35 and 109 of gestation. Correlations between caliper measurement and BW were moderate for both days. Quadratic equations for predicting BFD with caliper measurements were BFD (mm) = 6.458 + 0.052 × [Caliper measurement (unit)]^2 for day 35 of gestation, and BFD (mm) = 6.244 + 0.060 × [Caliper measurement (unit)]^2 for day 109 of gestation. The coefficients of determination (R^2; both $P < .001$) were 0.524 and 0.553 for days 35 and 109 of gestation, respectively.

Effects of caliper category on BFD, BCS, and BW. On day 35 of gestation, BFD, BCS, and BW increased with caliper category (all $P < .001$; Table 2). Similarly, on day 109 of gestation as caliper category increased, BFD, BCS, and BW increased (all $P < .001$). Sows in caliper category 4 had average BFD 15.8 and 17.2 mm for days 35 and 109, respectively, which are close to the recommended BFD for gestating sows.[1,9,16]

Effects of prefarrowing caliper category on farrowing and lactation performance

There were no differences in farrowing rate or completion rate among sows in different caliper categories measured on day 109 of gestation (Table 3). As caliper measurements increased, average daily feed intake (ADFI) of sows during lactation decreased ($P < .001$). Feed intake was

Figure 1: Distribution of backfat depth within each caliper category for sows on days A) 35 and B) 109 of gestation (x = median; box = 25 to 75 percentile; whisker = minimum to maximum; dot = outliers). Caliper readings were categorized as: Category 1 = 4.0-8.0 units; Category 2 = 8.5-10.0 units; Category 3 = 10.5-12.0 units; Category 4 = 12.5-14.0 units; and Category 5 = 14.5-18.0 units. 1 unit = 5 mm.

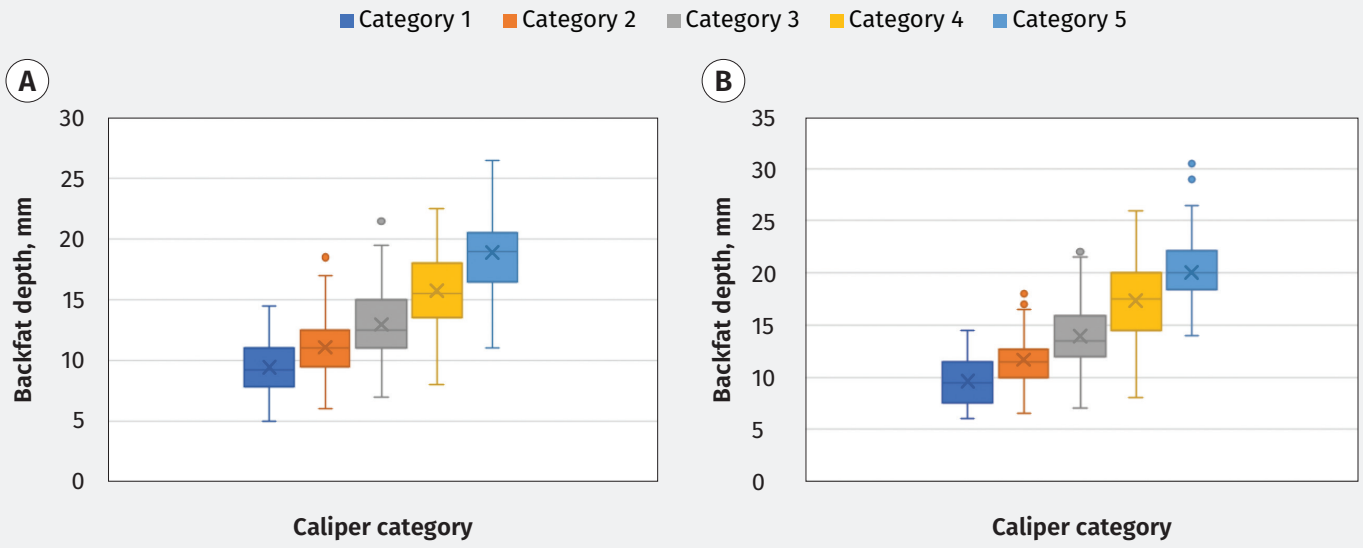
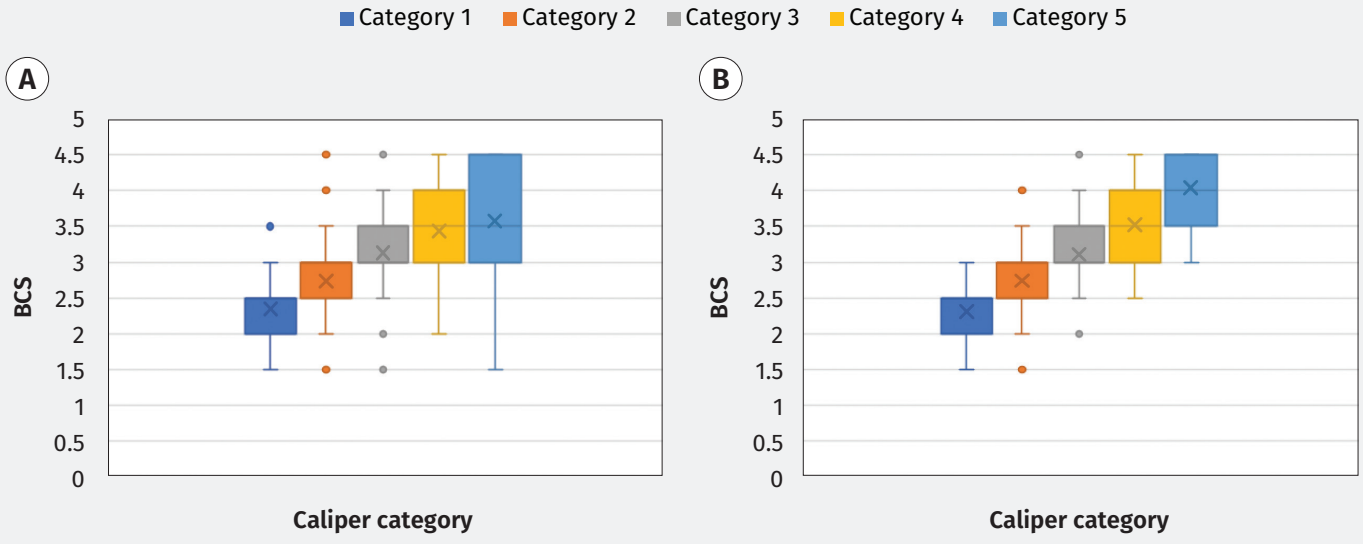


Figure 2: Distribution of visual body condition score (BCS) within each caliper category for sows on days A) 35 and B) 109 of gestation (x = median; box = 25 to 75 percentile; whisker = minimum to maximum; dot = outliers). Category readings were categorized as: Category 1 = 4.0-8.0 units; Category 2 = 8.5-10.0 units; Category 3 = 10.5-12.0 units; Category 4 = 12.5-14.0 units; and Category 5 = 14.5-18.0 units. 1 unit = 5 mm. Visual body condition score: Score 1 = emaciated; Score 2 = thin; Score 3 = ideal; Score 4 = fat; and Score 5 = obese (Coffey et al[14]), with a minimum score of 0.5.



highest for sows in category 1, and lowest for sows in caliper categories 4 and 5. At weaning, BFD and BW increased with caliper category ($P < .001$). Loss in BFD and BW during farrowing and lactation was lowest for sows in caliper category 1 and highest for sows in caliper categories 4 and 5. Sows in caliper category 2 tended ($P = .055$) to have more stillborn pigs than sows in caliper category 5. Caliper category did not affect litter size, litter weight at birth, or litter size after crossfostering, except that sows in caliper categories 1 and 2 weaned heavier litters than sows in caliper category 5 ($P = .03$). There were no interactions between caliper category and parity classification for any variables measured.

Discussion

In this study, we evaluated whether a Sow Caliper can accurately measure body condition of gestating sows by examining associations of caliper measurement with BFD, BCS, and BW. Data were collected at two stages of gestation: early gestation (day 35) and prefarrowing (day 109 of gestation). Strong positive correlations between caliper measurement and BFD indicate that caliper measurements reflect BFD at both stages of gestation. Quadratic equations were developed to estimate BFD from caliper measurement for early gestation and again prefarrowing. The coefficients of determination (R^2) indicate that caliper measurement explains 52% and 55% of variation in BFD early in gestation and prefarrowing, respectively. In general, the predicted BFD from these equations is consistent with descriptive data (Figure 1) and the data in Table 2, indicating that the predictions are acceptable. These equations may be specific to the genotype of sows involved in this study because body conformation of individual sows[18] may contribute to variation in caliper measurements. Indeed, these equations need to be further tested, but they provide a simple tool for producers to predict BFD from caliper measurements.

The BFD associated with each caliper category was not consistent across both stages of gestation. A specific caliper unit was related to a lower BFD in early gestation compared with prefarrowing.

Table 1: Correlation of Sow Caliper measurement with backfat depth, visual body condition score (BCS), and body weight of gestating sows

		Spearman coefficient*		
Caliper measurement	**No. of sows**	**Backfat**	**Visual BCS**	**Body weight**
D 35 of gestation	898	0.713	0.665	0.517
D 109 of gestation	871	0.751	0.750	0.516

* All coefficients are significant ($P < .001$).

Table 2: Mean (SE) backfat depth, visual body condition score (BCS), and body weight of sows in different Sow Caliper categories on days 35 and 109 of gestation

	Caliper category*					*P* value
	C1	**C2**	**C3**	**C4**	**C5**	
Mean parity (SD)	5.1 (2.2)	4.7 (2.3)	4.5 (2.3)	4.2 (2.5)	4.3 (2.5)	-
Day 35 of gestation						
No. sows	102	225	259	241	71	-
Backfat depth, mm	9.5 (0.3)^a	11.1 (0.2)^b	13.0 (0.2)^c	15.8 (0.2)^d	19.3 (0.4)^e	< .001
Visual BCS†	2.4 (0.1)^a	2.8 (0.1)^b	3.1 (0.1)^c	3.4 (0.1)^d	3.8 (0.1)^e	< .001
Body weight, kg	184.8 (1.9)^a	198.8 (1.4)^b	209.0 (1.4)^c	222.5 (1.4)^d	240.4 (2.6)^e	< .001
Day 109 of gestation						
No. sows	83	186	253	260	89	-
Backfat depth, mm	9.8 (0.4)^a	11.8 (0.3)^b	14.0 (0.3)^c	17.2 (0.3)^d	20.5 (0.4)^e	< .001
Visual BCS†	2.4 (0.1)^a	2.8 (0.1)^b	3.1 (0.1)^c	3.5 (0.1)^d	3.9 (0.1)^e	< .001
Body weight, kg	214.8 (2.4)^a	229.9 (1.8)^b	240.8 (1.7)^c	252.7 (1.7)^d	267.5 (2.6)^e	< .001

* Sow Caliper measurements were recorded on days 35 and 109 of gestation separately. C1 = 4.0-8.0 units; C2 = 8.5-10.0 units; C3 = 10.5-12.0 units; C4 = 12.5-14.0 units; and C5 = 14.5-18.0 units. 1 unit = 5 mm.

† Score 1 = emaciated; Score 2 = thin; Score 3 = ideal; Score 4 = fat; and Score 5 = obese (Coffey et al[14]).

^{abcde} Least squares means within a row without a common superscript differ ($P < .05$). Comparisons were performed using the Tukey-Kramer test adjusted for multiple comparisons. The Glimmix procedure was used for analysis of backfat depth and visual BCS. The Mixed procedure was used for analysis of body weight.

Table 3: Least squares means (SE) of performance parameters of sows in different Sow Caliper categories

	Caliper category*					*P* value
	C1	C2	C3	C4	C5	
No. sows assigned†	91	200	267	274	96	-
No. sows weaning a litter§	81	182	245	254	85	-
Farrowing rate, %‡	91.2	93.0	94.4	95.3	90.6	.41¶
Completion rate, %**	75.8	84.5	82.0	84.7	79.2	.29¶
Lactation ADFI, kg††	7.29 (0.17)[a]	6.85 (0.14)[b]	6.63 (0.13)[b]	6.08 (0.12)[c]	5.77 (0.18)[c]	< .001
At weaning§§						
Backfat, mm	9.3 (0.4)[a]	10.7 (0.3)[b]	12.7 (0.3)[c]	15.0 (0.3)[d]	18.1 (0.4)[e]	< .001
Body weight, kg	214.2 (2.7)[a]	224.0 (1.9)[b]	235.0 (1.8)[c]	243.6 (1.8)[d]	257.3 (2.9)[e]	< .001
Change during farrowing and lactation‡‡						
Backfat, mm	-0.6 (0.3)[a]	-1.0 (0.2)[ab]	-1.3 (0.2)[b]	-2.1 (0.2)[c]	-2.4 (0.3)[c]	< .001
Body weight, kg	-0.5 (1.8)[a]	-6.2 (1.4)[bc]	-5.8 (1.4)[b]	-9.2 (1.3)[cd]	-10.0 (2.0)[d]	< .001
Litter size, No.						
Total born	14.7 (0.4)	14.9 (0.3)	14.5 (0.2)	14.3 (0.2)	14.8 (0.5)	.49
Born alive	12.6 (0.4)	12.5 (0.3)	12.3 (0.2)	11.9 (0.2)	12.7 (0.5)	.33
Stillborn	1.5 (0.2)[fg]	2.0 (0.2)[f]	1.7 (0.1)[fg]	1.7 (0.1)[fg]	1.2 (0.2)[g]	.055
After crossfostering	11.1 (0.4)	11.3 (0.3)	11.1 (0.2)	11.2 (0.2)	11.1 (0.4)	.94
Weaned§§	10.3 (0.4)	10.5 (0.2)	10.2 (0.2)	10.4 (0.2)	10.1 (0.4)	.90
Litter weight, kg						
At farrowing¶¶	16.9 (0.5)	17.3 (0.3)	16.8 (0.3)	16.5 (0.3)	17.4 (0.5)	.19
At weaning§§	64.0 (1.3)[a]	63.5 (0.9)[a]	61.6 (0.8)[ab]	62.0 (0.8)[ab]	58.8 (1.5)[b]	.03

* Sow Caliper measurements recorded on day 109 of gestation were used. C1 = 4.0-8.0 units; C2 = 8.5-10.0 units; C3 = 10.5-12.0 units; C4 = 12.5-14.0 units; and C5 = 14.5-18.0 units. 1 unit = 5 mm.

† For sows that were culled before day 109 of gestation, caliper measurements recorded on day 35 of gestation were used for categorization.

§ Sows that farrowed and weaned a litter.

‡ Sows that farrowed as percentage of the total number of sows assigned to the study.

¶ Chi-square test (χ^2 = 2.5, *df* = 4 for farrowing rate; χ^2 = 5.0, *df* = 4 for completion rate).

** Sows that completed the study as percentage of the total number of sows assigned to the study. Sows that farrowed and were subsequently mated within a week after weaning their litters for the next breeding cycle were considered to have completed the study.

†† From the day of farrowing to the day of weaning.

§§ Mean (SD) weaning age of piglets was 18 (1.5) days.

‡‡ From day 109 of gestation to the day of weaning.

¶¶ Weight of live born.

[abcde] Least squares means within a row without a common superscript differ (*P* < .05). Comparisons were performed using the Tukey-Kramer test adjusted for multiple comparisons. The Glimmix procedure was used for analysis of backfat depth and litter size. The Mixed procedure was used for analysis of ADFI, body weight, and litter weight.

[fg] Least squares means within a row without a common superscript tend to differ (*P* < .10).

ADFI = average daily feed intake.

For instance, the mean BFD corresponding to caliper category 4 was 15.8 mm at day 35 of gestation and 17.2 mm at day 109. The quadratic regression equations also predict lower BFD on day 35 than on day 109 for the same caliper measurement. This discrepancy suggests that gestation stage may influence the relationship between caliper measurement and BFD. Thus, results from this study may only be applicable for sows in early gestation and prefarrowing. Relationship between BFD and caliper measurement during other stages of production needs to be assessed in future research.

Backfat depth between 18 and 20 mm is recommended for gestating sows before farrowing.[16,17] Generally, it is recommended that a commercial herd should have less than 20% sows with BFD lower than 15 mm before farrowing.[8] In the current study, caliper category 1 represents emaciated condition of sows, with more than 50% of the sows in this category having BFD lower than 10.0 mm on day 109. Backfat depth below 10 mm may represent emaciation,[8] and emaciated sows present animal welfare concerns.[3] Sows in caliper category 2 are also considered thin because about 50% of sows in this category had BFD lower than 11.6 mm prefarrowing. On the other hand, sows in caliper category 5 represent over condition, with 50% of the sows in this category having BFD greater than 20.1 mm prefarrowing. According to recommendations for BFD, sows in caliper category 4 were deemed optimal for body condition in the current study, with 75% in this category of sows having BFD above 14.5 mm. Using the quadratic equation at day 109 of gestation, the estimated lower and upper limits of BFD for sows in caliper category 4 are 15.6 and 18.0 mm, respectively.

Sows in caliper category 4 had lower ADFI and lost more BFD and BW during lactation, compared to sows in caliper category 3. However, these differences between sows in both caliper categories did not influence their litter performance. The number and weight of piglets farrowed and weaned were similar between sows in caliper categories 3 and 4. While sows in caliper category 3 performed well, their BFD was lower than the recommendation, with more than 50% of the sows in that category having BFD lower than 14 mm prefarrowing. It is worthwhile to note that in this study we only evaluated sow performance over one lactation. Severe loss in ADFI, BFD, and BW during lactation can be detrimental to subsequent reproductive performance, such as reduced litter weight and litter uniformity.[2,19] The long-term effect of Sow Caliper category on performance of lactating sows needs to be evaluated in future research.

Caliper category 4 (12.5 to 14.0 unit) is slightly lower than the caliper range of 14 to 15 units recommended by Knauer and Baitinger[11] based on litter size at weaning. We did not observe any difference in litter size weaned among sows in different caliper categories in the current study. One must recognize that the current study only included sows (parity 1-9) and did not include gilts. The recommended Sow Caliper range from this study may only apply to sows that have farrowed at least once and does not apply to gilts. Gilts need more backfat than mature sows to support maternal development and litter performance.[20,21] Therefore, the fact that no gilts were included in the current study may partially explain the recommended caliper range lower than that recommended by Knauer and Baitinger.[11]

In general, caliper measurement reflects BCS as indicated by positive correlations between the two variables on days 35 and 109 of gestation. The average BCS corresponding to the optimal caliper category 4 at prefarrowing was 3.5, which was slightly higher than the optimal BCS 3.0. This suggests that visual body condition scoring may overestimate body condition of gestating sows. Similar results were reported previously[8,9] that BCS overestimated body condition on commercial farms. For instance, the average BFD for sows in BCS 3 was 13.7 mm during gestation,[8] which is lower than the recommendations for BFD of gestating sows.[16,17] Apparently, the Sow Caliper can measure body condition of gestating sows more accurately compared to visual body condition scoring. Caliper measurement was only moderately correlated with BW in the current study, suggesting that caliper measurement is not a good indicator of BW. Moderate correlations between caliper measurement and BW were reported previously.[11]

Implications

Under the conditions of this study:

- Sow Caliper measurements were correlated strongly with BFD and BCS.
- The recommended caliper range for prefarrowing sows is 12.5 to 14.0 units.
- Sow Caliper measurement explains about 55% of variation in prefarrowing BFD.

Acknowledgments

The authors greatly appreciate the National Pork Board, the Pork Checkoff, and the Minnesota Agricultural Experiment Station for partial support of this project.

Conflict of interest

None reported.

Disclaimer

Scientific manuscripts published in the *Journal of Swine Health and Production* are peer reviewed. However, information on medications, feed, and management techniques may be specific to the research or commercial situation presented in the manuscript. It is the responsibility of the reader to use information responsibly and in accordance with the rules and regulations governing research or the practice of veterinary medicine in their country or region.

References

1. Charette R, Bigras-Poulin M, Martineau GP. Body condition evaluation in sows. *Livest Prod Sci*.1996;46:107-115.

2. Wientjes JGM, Soede NM, Knol EF, van den Brand H, Kemp B. Piglet birth weight and litter uniformity: Effects of weaning-to-pregnancy interval and body condition changes in sows of different parities and crossbred lines. *J Anim Sci*. 2013;91:2099-2107. **doi:10.2525/jas2012-5659**

3. Lavery A, Lawlor PG, Magowan E, Miller HM, O'Driscoll K, Berry DP. An association analysis of sow parity, live-weight and back-fat depth as indicators of sow productivity. *Animal*. 2019;13(3):622-630.

*4. National Pork Board. On-Farm Euthanasia of Swine: Recommendations for the Swine Producer. National Pork Board; 2016:3-18. Accessed September 16, 2020. **https://www.aasv.org/aasv/documents/SwineEuthanasia.pdf**

5. Quesnel H, Brossard L, Valancogne A, Quiniou N. Influence of some sow characteristics on within-litter variation of piglet birthweight. *Animal*. 2008;2:1842-1849.

6. Knage-Rasmussen KM, Houe H, Rousing T, Sorensen JT. Herd- and sow-related risk factors for lameness in organic and conventional sow herds. *Animal*. 2014;8(1):121-127.

7. Fitzgerald RF, Stalder KJ, Dixon PM, Johnson AK, Karrier LA, Jones GF. The accuracy and repeatability of sow body condition scoring. *Prof Anim Sci*. 2009;25(4):415-425.

*8. Young MG, Tokach MD, Goodband R, Nelssen JL, Dritz SS. The relationship between body condition score and backfat in gestating sows. *Kansas Agric Exp Station Res Rep*. 2001. Article 866. Accessed July 23, 2020. **https://newprairiepress.org/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=6706&context=kaesrr/**

9. Maes DGS, Janssens GPJ, Delputte P, Lammertyn A, de Kruif A. Back fat measurements in sows from three commercial pig herds: Relationship with reproductive efficiency and correlation with visual body condition scores. *Livest Prod Sci.* 2004;91:57-76. **doi:10.1016/j.livprodsci.2004.06.015**

10. Knauer MT, Baitinger DJ. The sow body condition caliper. *Appl Eng Agric.* 2015;31(2):175-178.

*11. Knauer M, Baitinger D. The sow body condition caliper, a paradigm change in sow management. National Hog Farmer. Published October 12, 2017. Accessed September 16, 2020. **https://www.nationalhogfarmer.com/animal-health/sow-body-condition-caliper-paradigm-change-sow-management/**

12. Li YZ, Cui SQ, Yang XJ, Johnston LJ, Baidoo SK. Minimal floor space allowance for gestating sows kept in pens with electronic sow feeders on fully slatted floors. *J Anim Sci.* 2018;96:4195-4208. **doi:10.2093/jas/sky282**

13. Li YZ, Gonyou HW. Comparison of management options for sows kept in pens with electronic feeding stations. *Can J Anim Sci.* 2013;93:445-452.

*14. Coffey RD, Parker GR, Laurent KM. Assessing sow body condition. Cooperative Extension Service, University of Kentucky;ASC-158. 1999.

*15. National Research Council. *Nutrient requirements of swine.* 11th ed. National Academy Press. 2012.

*16. Johnson C, Stalder K, Karriker L. Sow Condition Scoring Guidelines. National Hog Farmer. Published April 15, 2006. Accessed July 20, 2020. **https://www.nationalhogfarmer.com/mag/farming_sow_condition_scoring/**

17. Houde AA, Methot S, Murphy BD, Bordignon V, Palin MF. Relationship between backfat thickness and reproductive efficiency of sows: A two-year trial involving two commercial herds fixing backfat thickness at breeding. *Can J Anim Sci.* 2010;90:429-436.

18. Whittemore CT, Schofield C. A case for size and shape scaling for understanding nutrient use in breeding sows and growing pigs. *Livest Prod Sci.* 2000;65:203-208.

19. Young LG, King GJ, Shaw J, Quinton M, Walton JS, McMillan I. Interrelationships among age, body weight, backfat, and lactation feed intake with reproductive performance and longevity of sows. *Can J Anim Sci.* 1991;71:567-575.

20. Roongsitthichai A, Tummaruk P. Importance of backfat thickness to reproductive performance in female pigs. *Thai J Vet Med.* 2014;44(2):171-178.

21. Farmer C, Comi M, Duarte CRA, Vignola M, Chargu P, Palin MF. Differences in body condition of gilts that are maintained from mating to the end of gestation affect mammary development. *J Anim Sci.* 2016;94:3206-3214.

* Non-refereed references.