Principal Descriptors of Body Condition Score in Holstein Cows

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ABSTRACT

The objective of this study was to assess objectively the ability of observers to assess body condition of dairy cows. Four observers independently assigned a body condition score (five-point scale, .25 increments) and described the appearance of seven body regions of 225 Holstein cows. Areas described were the thurl region, ischial and ileal tuberosities, ilio-sacral and ischio-coccygeal ligaments, transverse processes of the lumbar vertebrae, and spinous processes of the lumbar vertebrae. An absolute body condition score was designated for each cow based on the modal body condition score for all observers. If there was no modal body condition score, the mean score was used for the absolute body condition score. Statistical analysis of principal components was used to examine the relationship between body region description and absolute body condition score. Descriptions of body regions were highly correlated across all absolute body condition scores. Four principal component vectors explained 83.6% of the variation of the body region correlation matrix. The first principal latent vector accounted for 55% of the variation and was uniformly correlated with all body regions. Analysis of variance of first principal latent vector as the dependent variable and absolute body condition score as the class variable indicated that body condition could be separated into .25 units between 2.5 and 4.0, inclusively. Below 2.5 and >4.0, body condition could only be separated by .5 units. Distinct changes in specific body regions were associated with change in absolute body condition score. Observers agreed with the absolute score 58.1% of the time, deviating by .25 units 32.6% of the time. A body condition score can be given to a cow based on principal descriptors of specific body regions between 2.5 and 4.0 by .25 units.
(**Key words**: body condition score, principal descriptors)

Abbreviation key: **BCS** = body condition score, **MBCS** = modal body condition score, **PCV** = principal component vector.

INTRODUCTION

Evaluation of body condition using a body condition score (**BCS**) is a useful management tool to assess body fat stores of Holstein dairy cows (3, 11, 15, 16). Excessive body condition has been recognized as a risk factor for health problems in dairy cows (9) and as a factor influencing feed intake and milk production (6). Excessive loss of body condition has been associated with lowered reproductive performance and reduced milk production (6, 13). Thus, BCS has received considerable attention as a tool to aid in the management of nutritional programs in dairy herds (7, 12, 13, 15).

In general, in the United States, dairy cows are given a BCS based on a five-point scale outlined by Wildman et al. (16) based on fat cover over the lumbar and pelvic regions. Emaciated cows are scored 1; thin cows, 2; average cows, 3; fat cows, 4; and obese cows, 5. Observers often refine the scale by using plus or minus signs, in .25 to .5 units, or an expanded nine-point scale to assess more subtle changes in body fat than are allowed by the unit increments (3, 4, 11, 15). The degree to which BCS may be divided based on body

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region description has not been rigorously tested.

A BCS is assigned to a cow based on the appearance of tissue cover over the bony prominences in the back and pelvic regions (3, 7, 8, 12, 13, 16). Specific regions include the spinous and transverse processes of the lumbar vertebrae, the ileal (hook bone) and ischeal (pin bone) tuberosities, the ileo-sacral and ischeal-coccygeal ligaments, the tail head, and the thurl region (or rump, the region bounded anteriorally by the ileal tuberosity and ileo-sacral ligament, caudally by the ischeal tuberosity and the ischeal-coccygeal ligament, and ventrally by the greater trochanter of the femur). Tissue cover may be estimated via palpation, visual inspection, or both (4, 16).

Because of the subjective nature of body condition scoring, extension centers and industry representatives have developed charts, pictures, and descriptions to define specific characteristics of each BCS (3, 4, 5, 7, 8, 12, 13). Typically, for each BCS, a description of lumbar, pelvic, and tail head regions is expressed. The person interested in developing skills in body condition scoring must integrate these descriptions into a useful system. A chart has been produced to facilitate developing skills in body condition scoring (4, 8). The use of a chart involves assessing multiple body regions and integrating this information into an overall BCS. The description of multiple body regions may contain redundant information, or the change in appearance of a region may be too subtle to be described succinctly with slight changes in BCS, such as subtle changes in angularity or roundness of a body region. Thus, descriptions and charts may be more complex than needed to assign a cow a BCS.

Ideally, a scoring system should be simple, repeatable, and easy to convey to producers and industry personnel. Because changes in body fat occur in a coordinated fashion throughout the body (1, 17), change in appearance of body regions is not independent. Change within specific body regions may indicate score categories, rather than an integrated description of all body regions at a given BCS. Unique descriptors may exist that distinguish each characteristic BCS and ease training and improve repeatability between observers. Principal component analysis is a statistical method that enables the reduction of a large number of variables to a smaller, more coherent set of variables (2). Principal component analysis is useful for reducing highly correlated observations to a few principal descriptors, and it facilitates identifying principal descriptors (2, 14). A principal component latent vector (**PCV**) (eigenvector) is a linear combination of the original variables based on the correlation or covariance of the original variables (2). The principal components are uncorrelated and capture most of the information in the original data (2). The hypothesis of this study was that principal descriptors of body score could be identified to describe a specific BCS. In addition, PCV of descriptors of BCS would enable rigorous testing of the ability to separate BCS classes on increments of .25 or .5 unit.

MATERIALS AND METHODS

Two hundred and twenty-five lactating Holstein cows from a 400-cow commercial dairy were used for the study. Cows were housed in four lots, grouped by stage of lactation and production, and were between 5 to 300 d of lactation. Cows were milked three times a day and fed a total mixed ration twice a day from bunk managers. Rolling herd average was over 10,000 kg of milk. Rations for production groups were balanced for 41, 32, and 23 kg of milk based on NRC recommendations (10).

Cows were locked in head gates at the feed manger at the morning feeding. Four observers (three experienced and one less experienced with body condition scoring) viewed cows independently, walking behind the cows. Both visual and tactile cues were allowed. Observers scored cows separately by lot and rotated lots so no two observers were in a lot at the same time and no communication could occur between observers.

For each cow, observers recorded cow ear tag identification, BCS, and a description of the appearance of the spinous and transverse processes of the lumbar vertebrae, the ileal and ischeal tuberosities, the ilio-sacral and ischeal-coccygeal ligaments, and the thurl and tail head regions (Table 1). Descriptions of each body region were digitalized for statistical analysis. For example, the ischial or ileal tuberosity may be described as angular (coded as 1), angular-round (coded as 2), round (coded

TABLE 1. Categorization of body condition regions.

Region	Description			
Ischial tuberosity	Not visible	Round	Angular-round	Angular
Ileal tuberosity	Not visible	Round	Angular-round	Angular
Sacral ligament	Not visible	Slightly visible	Visible	Sharp
Coccygeal ligament	Not visible	Slightly visible	Visible	Sharp
Thurl region	Flat	U	V	V, sharp
Transverse processes of the lumbar vertebrae[1]				
Appearance of distal edge of processes	Not visible	Slightly visible	Visible	Sharp
Length of process visible	None	Slightly visible	Visible	Sharp
Spinous processes of lumbar vertebrae[2]				
Appearance of the dorsal edge of the processes	Not visible	Slightly visible	Visible	Sharp
Slope from midline of spine to loin edges	Flat	Sloped	Slightly curved	Sharply curved

[1]Appearance of distal edge of the process: not visible – no distinct edge apparent; slightly visible – edge of process apparent, rounded and slightly scalloped; visible – edge of the processes are visible, scalloped appearance, rounded; and sharp – edge of the processes are visible, scalloped and sharp. Length of processes: none – process not visible; slightly visible – up to .25 of length apparent; visible – .25 to .5 of length visible; and sharp – .5 to .75 of length visible.

[2]Appearance of the dorsal edge of the process: not visible; slightly visible – rounded; visible – dull in appearance; and sharp – all processes distinct along back. Slope from midline of spine to loin edges: flat – level from midline to tip of transverse processes; sloped – linear slope from midline to tip of transverse processes; slightly curved – slight parabola from midline to tip of transverse processes; and sharply curved – parabolic from midline to tip of transverse processes.

as 3), partially visible (coded as 4), and not visible (coded as 5). Data for each observer for cow and body region provided the data base for statistical analysis.

Statistical Analysis

The mode of the BCS of the four observers was assigned to define an absolute BCS (MBCS) for an individual cow. If no MBCS existed, the mean score for the four observers was used to define the MBCS. Each observer score was subtracted from the MBCS to examine the difference of observers from the MBCS for each cow. In addition, each observer BCS was subtracted from the other to examine the distribution of BCS for each cow across observers.

Principal component analysis in SAS statistical software (14) was used to examine the relationship of body region description to MBCS (2). Analysis of principal components reduces the dimensionality of a set of correlated variables. Because BCS involves assessment of seven to eight body regions, which are correlated with each other, principal components analysis can be used to determine whether the number of variables needed to describe BCS can be reduced. The PCV (eigenvectors or weight vectors) are fit to the correlation matrix of the variables, each variable contributes a weight, and the sum of the weights is the latent root, or the principal components statistic (2). Seven latent vectors are generated for seven variables. Each latent vector is composed of seven weights, each associated with a body region variable. The PCV 1 is the line of closest fit to the data matrix. The PCV 2 is the line of closest fit to the residuals of PCV 1 and is orthogonal to PCV 1. The goal of PC analysis is to reduce the variables needed to describe a data set (2). The PCV 1 is of the form:

$$\text{PCV } 1 = \sum_{i=1}^{p} a_{1i}X_i$$

a_{1i} = latent vector of the variable x, and
x_i = variable i, under the constraint that $\sum_{i=1}^{p} a_{1i}^2 = 1$.

The PCV 2 vector minimizes the variance of

$$\text{PCV } 2 = \sum_{i=1}^{p} a_{2i}X_i$$

under the constraint that PCV 2 is uncorrelated with PCV 1. In addition, for PCV 2, $\sum_{i=1}^{p} a_{2i}^2 = 1$. The PCV 1 has the largest sum of squared correlations with the original variables, and PCV 2 has the second largest sum. Each succeeding PCV explains less of the variance of the correlation matrix of the initial variables. The mean value for each PCV is zero (2).

The eigenvector with equal weighting for all seven body regions, PCV 1, was used as a dependent variable, and MBCS was used as a class variable to test the degree of resolution of BCS based on description of the seven body regions. Thus, separation of BCS by .25 units could be statistically tested using PROC GLM of SAS. The mathematical model was of the form:

$$PCV_{ijk} = \mu_l + MBCS_j + \epsilon_{ijk}$$

where

PCV_{ijk} = PCV 1,
μ_l = overall mean of PCV 1,
$MBCS_j$ = MBCS j, and
ϵ_{ijk} = residual error.

The PDIFF procedure of SAS (14) was used to make preplanned comparisons. Comparisons were only examined for parameters with significant effects in the GLM model and if the overall fit of the model was significant. Correlation between observer BCS and the MBCS were analyzed using the correlation procedure in SAS (14).

For each latent PCV, each of the seven body region variables in the data set has a weight (square root of the latent root times the element weight for an independent variable equals the correlation or loading of that variable for that PCV) that indicates the contribution of the variable to that specific latent PCV. These coefficients can be used to rank the relative importance of the variables for each latent PCV. The main components of each latent PCV may be used to specify body regions contributing to specific BCS classes.

RESULTS AND DISCUSSION

Descriptive statistics for BCS and observer are presented in Tables 2 through 4. Cows ranged in MBCS from 1.50 to 4.50, and mean MBCS was 3.21 (Table 2). Mean BCS was not different for observers 1, 2, and 3, and mean BCS for observers 1, 2, and 3 was not different from the mean MBCS. Mean BCS for observer 4 was lower than BCS for observers 1, 2, and 3 and MBCS (Table 2). Range in BCS was similar for observers 1 and 2 and slightly narrower for observers 3 and 4 (Table 2).

Correlation among observers for BCS was high and ranged from .763 to .858 (Table 3). Observer 4 had the lowest correlation with other observers. Correlation with MBCS was >.90 ($P < .0001$) for observers 1, 2, and 3 and was .830 for 4 (Table 3). Higher correlation for each observer with MBCS than with individual observer BCS was expected, because MBCS was central relative to the score for all four observers.

Differences from MBCS for each observer are presented in Table 4. Across all observers, 58.1% of the scores were identical to MBCS (Table 4). Scores of observers 1, 2, and 3

TABLE 2. Descriptive statistics of least squares mean body condition score (BCS) for four observers in Holstein dairy cows (n = 225).

	BCS	SEM	Range
Modal BCS[1]	3.21	.04	1.5–4.50
Observer			
1	3.21[a]	.04	1.50–4.50
2	3.21[a]	.04	1.50–4.75
3	3.11[a]	.05	1.75–4.25
4	2.80[b]	.08	1.00–4.00

[a,b]Means within a column followed by different superscript letters differ ($P < .05$).

[1]Highest frequency BCS for each cow or average if no model BCS.

TABLE 3. Correlation coefficients between observers and modal body condition score (MBCS) (n = 225).

	Observer			
Observerer	2	3	4	MBCS[1]
1	.858****	.838****	.833****	.935****
2	. . .	.880****	.842****	.950****
3	. . .	. . .	.763****	.939****
4	. . .	. . .	. . .	.830****

[1]Highest frequency body condition score for each cow or average of scores if no modal score.

****$P < .0001$.

TABLE 4. Distribution of differences from modal body condition score (MBCS).[1]

Difference	Difference by observer[2]				
	All	1	2	3	4
	(%)				
.50	3.0	2.4	5.6	1.8	1.4
−.25	14.0	5.6	27.8	9.6	8.2
0	58.1	64.0	58.0	67.1	27.0
+.25	18.6	24.0	8.6	19.2	30.0
+.50	3.8	3.2	0	1.8	17.8
+.75	1.9	0	0	0	12.3
+1.00	.2	0	0	.6	0
+1.25	.4	0	0	0	2.7

[1]Difference = (Modal BCS minus observer BCS), where BCS = body condition score. The MBCS is the highest frequency BCS for each cow or average of scores if no modal score.

[2]Observers 1, 2, and 3 were experienced, but observer 4 was less experienced in body condition scoring.

agreed with the MBCS on 58.0 to 67.1% of observations. Differences for all observers were distributed uniformly around zero difference (14.0% at −.25 and 18.6% at .25), and +/ −.25 differences accounted for 90.7% of the difference in observations (Table 4). Thus, particularly for observers 1, 2, and 3, BCS were usually within a .25 unit. Observer 4 was only within .25 unit of the MBCS 65% of the time, indicating the need for further training of this individual.

The variation in BCS for trained observers appears to be .25 units for 40% of observations, when cows are scored on a scale divided into .25 units. This result suggests that a change in .25 body condition units cannot be ascertained by one individual from two consecutive observations over one time period. To ascertain a change in body condition of .25 units requires two observations on a cow at each time period, either by two independent observers scoring cows simultaneously or by one observer repeating the observation at a later time period that day or the next.

Descriptions of each body region across MBCS classes are highly correlated and therefore lend themselves to PC analysis ($P < .0001$; Table 5). The description of the ischeal tuberosity was most highly correlated with descriptions of the ileal tuberosity (r = .602; $P < .0001$), the thurl region (r = .529; $P < .0001$), and the sacral ligament (r = .540; $P < .0001$). Description of the transverse processes of the lumbar vertebrae (the loin region) was most correlated with descriptions of the spine (r = .590; $P < .0001$), the sacral ligament (r = .588; $P < .0001$), and the thurl region (r = .548; $P < .0001$). The tailhead had the lowest correlation with other body region descriptors (all .2 < r <.4; $P < .0001$). The description of the thurl region was highly correlated with all other body regions (r >.5) except the tail head (r = .235; $P < .0001$). The description of the spine was most correlated with the sacral ligament (r = .588; $P < .0001$), the thurl region (r = .535; $P < .0001$), and the loin region (r = .590; $P < .0001$).

The latent roots (variances) and the latent PCV (eigenvectors) for the correlation matrix for the seven independent variables are presented in Table 6. The latent root for PCV 1 is 3.856 (Table 6), indicating that PCV 1 accounts for .551 (3.856/7.00 = .551) of total variance of the correlation matrix. The PCV 1, 2, 3, and 4 account for .551, .125, .095, and

TABLE 5. Correlation matrix of body region descriptions across four observers in Holstein cows (n = 225).

	Body region					
	Ileal tuberosity	Loin processes	Coccygeal ligament	Thurl region	Sacral ligament	Spinous processes
Ischial tuberosity	.602****	.406****	.351****	.529****	.540****	.479****
Ileal tuberosity		.431****	.326****	.516****	.569****	.478****
Loin processes			.256****	.548****	.588****	.590****
Coccygeal ligament				.235****	.342****	.258****
Thurl					.611****	.535****
Sacral ligament						.588****

****$P < .0001$.

TABLE 6. Latent principal component vectors (PCV; eigenvectors) and corresponding latent roots (variance) for body condition score descriptions based on the correlation of body region appearance in 225 Holstein cows.

	PCV						
Region	1	2	3	4	5	6	7
Ischial tuberosity	.386	.199	−.506	−.115	.499	.466	−.275
Ileal tuberosity	.389	.140	−.490	−.234	−.630	−.086	.361
Loin processes	.381	−.305	.485	.010	−.271	.670	.061
Coccygeal ligament	.245	.852	.430	.096	.048	−.560	.123
Thurl region	.399	−.233	−.096	.712	.262	−.205	.399
Sacral ligament	.425	−.078	.075	.162	−.259	−.369	−.760
Spinous processes	.393	−.249	.261	−.624	.379	−.380	.193
Latent root (variance)	3.856	.873	.668	.454	.415	.380	.353
Proportion of total variation explained	.551	.125	.095	.065	.059	.054	.050
Cumulative total	.551	.676	.771	.836	.895	.949	1.000

.065 of the variation of the correlation matrix, respectively, and these four PCV describe .836 of the total variance of the seven variables used for BCS.

The contribution (weight) of each body region to each eigenvector is also presented in Table 6. Each body region contributes almost equally to PCV 1 (.245 to .393). Thus, PCV 1 is a vector that calculates a latent root for the overall appearance of a cow based on the description of all body regions and is a proxy for BCS.

The coccygeal ligament contributes the greatest weight to PCV 2 (Table 6; .852), which principally describes changes in the tailhead. The PCV 3 has highest positive weights for the loin and tailhead (.485 and .430, respectively) and negative loadings of a similar magnitude for the hook and pin bones (−.490 and −.506, respectively); PCV 3 largely describes change in the loin and tailhead relative to change in the hook and pin bones. The PCV 4 has highest loadings for the thurl region (.712) and spine (−.624), describing changes in the thurl region relative to the spine.

Mean PCV 1 for each MBCS class is presented in Table 7. The PCV 1 changes as MBCS changes, decreasing uniformly as MBCS increases. The values for PCV 1 are different for every MBCS class from 2.25 through 4.25. Change in descriptions of these seven body regions are sufficient to score cows by .25 units from 2.25 to 4.25. At <2.25 and >4.25, cows can only be separated by .50 units with the descriptions employed in this study. It is not clear if the reduced resolution of BCS <2.25 and >4.25 was due to insufficient body

TABLE 7. Principal component vector 1 for modal body condition score (n = 225).[1]

BCS	Frequency	PCV 1	SEM
	(%)		
1.50	1.0	4.23[a]	.45
2.00	2.8	3.89[ab]	.28
2.25	6.8	3.37[ab]	.17
2.50	7.3	2.23[c]	.17
2.75	17.6	1.55[d]	.11
3.00	24.9	.70[e]	.09
3.25	12.6	−.13[f]	.09
3.50	10.6	−.92[g]	.11
3.75	9.0	−1.65[h]	.11
4.00	2.3	−2.18[i]	.16
4.25	3.8	−2.87[j]	.21
4.50	1.5	−3.10[j]	.34

[1]Regression equation (SEM in parentheses) for predicting principal component vector (PCV) 1:

$$\begin{aligned}\text{PCV 1} = & -5.3 + \underset{(.02)}{(.43 \times \text{hook})} + \underset{(.02)}{(.41 \times \text{pin})} \\ & + \underset{(.08)}{(2.14 \times \text{loin})} + \underset{(.03)}{(.32 \times \text{tail})} \\ & + \underset{(.02)}{(.57 \times \text{thurl})} + \underset{(.02)}{(.43 \times \text{sacral})} \\ & + \underset{(.01)}{(.37 \times \text{spine})}\end{aligned}$$

where hook = ileal tuberosity (3 = angular, 2 = angular/round, 1 = round, 0 = not visible), pin = ischeal tuberosity (3 = angular, 2 = angular/round, 1 = round, 0 = not visible), loin = visible edges to spine of the transverse processes of the lumbar vertebrae (0, .10, .25, .50, .75, 1.00), tail = coccygeal ligament (4 = sharp, 3 = visible, 2 = dull, 1 = not visible), thurl = appearance of the rump angle formed by the ischeal-ileal tuberosities and greater trochanter of the femur (4 = "V", 3 = "V-", 2 = "U", 1 = flat, 0 = round), sacral = sacral-ileal ligament (3 = sharp, 2 = visible, 1 = dull, 0 = not visible), and spine = appearance of spinous processes of lumbar vertebrae (3 = sharp, 2 = round, 1 = dull, 0 = flat).

description in these cows or to insufficient number of cows in these categories. Because most cows on farms have BCS between 2.00 to 4.00, description of these seven regions is sufficient to separate cows by .25 body condition units.

Typical descriptions of each body region for BCS classes are presented in Table 8 along with predicted PCV 1 and the 95% confidence limit for the observed PCV 1. These descriptions were used to develop a body condition chart based on unique changes in body region for each BCS class (Table 9). For example, cows with an appearance of a "V" at the thurl region were always classified as a BCS ≤3.0, and cows with a "U" appearance at the thurl were always classed ≥3.25. The thurl region separated cows into those ≤3.00 BCS ("V" appearance) or cows >3.00 BCS (a "U" appearance).

Cows with a BCS of 3.0 were likely to have rounded hook and pin bones (Tables 8 and 9). Cows with a BCS of 2.75 were likely to have an angular hook bone with a rounded pin bone (Table 8). At other BCS classes, the hook and pin bone tended to be similar in description.

The sacral ligament was not likely to be visible in cows with BCS ≥4.00. This ligament was likely to be obscured by fat in cows >3.75 and defines a unique class differentiation.

TABLE 8. Principal descriptor of each body region for each body condition score (BCS) class and observed and predicted principal component vector (PCV) 1.[1]

	BCS											
Body region	1.50	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50
Ischial tuberosity	ANG	ANG	ANG	ANG	ANG	RND	RND	RND	RND	RND	RND	RND
Ileal tuberosity	ANG	ANG	ANG	A/RD	RND	RND	RND	RND	RND	RND	RND	RND
Loin edges	1.00	.50	.25	.25	.25	.10	.10	.10	0	0	0	0
Coccygeal ligament	SHP	SHP	VIS	VIS	VIS	VIS	VIS	VIS	DUL	NV	NV	NV
Thurl region	V	V	V	V	V	V	U	U	U	U	U	FLT
Sacral ligament	SHP	SHP	SHP	VIS	VIS	VIS	VIS	VIS	DUL	NV	NV	NV
Spine	SHP	SHP	SHP	RND	RND	RND	RND	RND	RND	RND	DUL	FLT
Predicted PCV 1 based on above descriptions[2]	5.33	4.26	3.40	2.17	1.75	.57	.00	−.89	−1.86	−2.30	−2.67	−3.62
Observed PCV 1 (95% confidence bound)[3]												
Upper	3.67	3.33	3.03	1.89	1.33	.52	−.31	−1.14	−1.87	−2.50	−3.29	−3.78
Lower	4.79	4.45	3.71	2.57	1.77	.88	.05	−.70	−1.43	−1.86	−2.45	−2.42

[1]ANG = Angular appearance, RND = rounded appearance, A/RD = angular-rounded appearance, SHP = sharp appearance, DUL = visible but dull in appearance, VIS = visible easily, NV = not visible, FLT = flat appearance of spine or the appearance of shape of boundaries formed by ischeal tuberosity, illeal tuberosity and greater trochanter of femur, V = appearance of shape of boundaries formed by ischeal tuberosity, illeal tuberosity and greater trochanter of femur, and U = appearance of shape of boundaries formed by ischeal tuberosity, illeal tuberosity, and greater trochanter of femur.

[2]PCV 1 (SEM in parentheses):

$$\text{PCV 1} = -5.3 + \underset{(.02)}{(.43 \times \text{hook})} + \underset{(.02)}{(.41 \times \text{pin})} + \underset{(.08)}{(2.14 \times \text{loin})} + \underset{(.03)}{(.32 \times \text{tail})} + \underset{(.02)}{(.57 \times \text{thurl})} + \underset{(.02)}{(.43 \times \text{sacral})} + \underset{(.01)}{(.37 \times \text{spine})}$$

where hook = ileal tuberosity (3 = angular, 2 = angular/round, 1 = round, 0 = not visible), pin = ischeal tuberosity (3 = angular, 2 = angular/round, 1 = round, 0 = not visible), loin = visible edges to spine of the transverse processes of the lumbar vertebrae, (0, .10, .25, .50, .75, 1.00), tail = coccygeal ligament (4 = sharp, 3 = visible, 2 = dull, 1 = not visible), thurl = appearance of the rump angle formed by the ischeal-ileal tuberosities and greater trochanter of the femur (4 = "V", 3 = "V-", 2 = "U", 1 = flat, 0 = round), sacral = sacral-ileal ligament (3 = sharp, 2 = visible, 1 = dull, 0 = not visible), and spine = appearance of spinous processes of lumbar vertebrae (3 = sharp, 2 = round, 1 = dull, 0 = flat).

[3]Observed PCV 1 based on descriptions of body regions from four observers on 225 Holstein cows using modal BCS as classification variable; 95% confidence limit based on standard error of the least squares mean of PCV 1.

Cows with no visible sacral ligament will always be ≥4.0 and may be considered too fat for most dairy operations. The sacral ligament is visible in all cows <4.00, but is sharper in appearance in cows with a BCS ≤3.00.

Using the latent PCV and descriptors of MBCS, body condition can be reduced to a decision chart (Table 9). First, the observer should look at the thurl region (the rump). The thurl region defines cows at a BCS ≤3.00 ("V" in appearance) and ≥3.25 ("U" in appearance). If the thurl has a "V" appearance, the cow has a BCS of ≤3.00. If the observer sees a "V", hook and pin bones should be observed next. If both are rounded, the cow should have a BCS of 3.00; if the hook bone is angular and the pin bone rounded, BCS should be 2.75; if both are angular, BCS should be ≤2.50. Palpation of the pin bone can be used to distinguish a BCS 2.50 from BCS 2.25; the pin bone will have a palpable fat pad if BCS of the cow is 2.50 and will not if BCS of the cow is ≤2.25. Less than half the transverse processes of the lumbar vertebrae are visible in a cow with a BCS of 2.50 compared with half or more in a cow with BCS <2.50. In addition, the spine will be rounded in cows with a BCS of 2.50 but sharp in cows with a BCS of ≤2.25. The loin and spine are useful in classifying cows when they are ≤2.50, but are similar in appearance in cows from a BCS of 2.75 through 3.5. The subtle changes in the loin and spine are difficult to describe from BCS 2.75 through 3.5.

Cows with a "U"-shaped thurl region are 3.25 or higher in BCS. In these cows, the hook and pin bones will always appear rounded; thus, they contribute no useful information until cows are fat enough that they are not visible (cows above a 4.50, data not shown). Changes in the sacral and coccygeal ligaments largely describe change in BCS in cows from 3.25 to 4.00. If both coccygeal and sacral ligaments are distinctly visible, cows have BCS 3.25. If the coccygeal ligament is faintly visible and the sacral ligament distinct, cows have BCS 3.50. If the coccygeal ligament is not visible, and the sacral ligament is faintly visible, cows have BCS 3.75. If the sacral and coccygeal ligaments are not visible, the cow has BCS ≥4.00.

Primarily the tips of the transverse processes of the lumbar vertebrae are visible (.10 of the loin edges are apparent) from a 3.25

TABLE 9. Decision chart for body condition score (BCS) based on principal component descriptors of body regions. Unique classifiers for each score category.

	BCS												
Body region	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00
Thurl	V					U					flat		rounded
Ileal tuberosity	angular				rounded							just visible	not visible
Ischial tuberosity	angular		fat pad palpable	rounded							not visible		
Transverse processes of lumbar vertebrae	>.5 visible	.25 to .50 visible				.10 to .25 visible		only tips visible		tips not visible			
Coccygeal ligament	visible						just visible	not visible					
Sacral ligament	visible							just visible	not visible				

to a 3.75 BCS; thus, these changes are not distinct over this range. The spine region begins to look flat from BCS ≥3.75 but is not consistently described as flat until cows are >BCS 4.00.

To distinguish cows from BCS 4.00 to 4.50, the pin bone disappears in fat, and the tail head no longer has a depression >4.25. As cows become fatter (BCS >4.5; data not shown), the hook bone is no longer visible, and the thurl flattens and becomes round. The loin edges are not apparent in cows with a BCS ≥4.00; no scalloping along the loin edges is observed in those cows.

CONCLUSIONS

Descriptions of seven body regions is sufficient to categorize cows by .25-unit increments from BCS 2.25 to 4.00. The BCS may be simplified using principal descriptors for unique changes at each BCS class. This information may be used to construct a BCS decision tree. Observers agree 58 to 67% of the time when independently scoring cattle body condition; 21 to 34% of the time, observers differ by +/-.25 units.

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