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Short communication: Differences in genetic merit for visually-assessed body condition score materialises as phenotypic differences in tactile-based body condition score in commercial dairy cows

D.P. Berry [a,*], M.M. Kelleher [b]

[a] Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy P61 P302, Co. Cork, Ireland
[b] Irish Cattle Breeding Federation, Highfield House, Shinagh, Bandon P72 X050, Co. Cork, Ireland

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ABSTRACT

Body condition score (**BCS**) is a known risk factor for cow health and well-being. Many different BCS scales and systems for assessment exist;while the scales used for assessing BCS vary, differences in how BCS is assessed (i.e., visual versus visual plus tactile) and the extent of training and experience of the assessor (i.e., professional linear classifiers versus producers) also contributes to the underlying variability. Registered dairy cows globally are routinely assessed for linear type traits which describe biological extremes in the morphological attributes; BCS and a correlated trait angularity are within this suite of traits assessed. These linear-type data are used to generate estimates of genetic merit (predicted transmitting ability), but how these estimates manifest themselves as phenotypic differences when assessed by producers on commercial multiparous cows has never been quantified. To evaluate this, 58 440 phenotypic BCS records from 48 823 lactations in 38 608 cows were used. Associations were undertaken using linear mixed models relating phenotypic BCS to genetic merit after accounting for nuisance factors. Differences in genetic merit for either BCS or angularity (assessed visually by professionals on a 1 to 9 scale just once during lactation in primiparous registered cows) translated to phenotypic difference in BCS (assessed by producers using both tactile and visual assessment on a 1 to 5 scale across lactation in commercial dairy cows). The partial correlation between test phenotypic BCS and genetic merit for either BCS or angularity was 0.13 and 0.10, respectively. Based on the model coefficients estimated in the present study, the mean expected difference in phenotypic BCS on a 1 to 5 scale between the top and bottom 10% on genetic merit for BCS or angularity was 0.28 and 0.31 units, respectively. Results from the present study clearly provide confidence that genetic merit for BCS or angularity based on a single visual assessment in primiparous cows is useful to breed for cows of better body condition, irrespective of stage of lactation or parity.

Implications

Whether differences in genetic merit translate to differences in actual performance is often questioned, especially where the trait defining the measure of genetic merit is somewhat different to the trait of commercial interest. The results from this study demonstrate that differences in genetic merit for body condition score or angularity based on a single visual assessment by professionals in registered primiparous dairy cows translate to differences in body condition score among commercial dairy cows across parities and stages of lactation.

Introduction

Body condition score (**BCS**) is a quick, subjective, non-invasive and inexpensive means of estimating fat stores in dairy cows. The importance of BCS as a management tool on dairy farms has been well described (Roche et al., 2009). Genetically, BCS is also well known to be correlated with milk production (Berry et al., 2003), reproductive performance (Pryce et al., 1998; Berry et al., 2003) and health (Pryce et al., 1998) in dairy cows. While BCS is a relatively simple and easy-to-learn technique, the actual recording of BCS in databases for use in genetic evaluation is lacking. Although technologies (Hansen et al., 2018) and approaches (Ferguson et al., 2006) to the automation or off-line assessment of BCS exist, the return-on-investment of such approaches may not always be obvious, especially in small herds. Therefore, alternative strategies for collecting such data for use in breeding

* Corresponding author.
E-mail address: donagh.berry@teagasc.ie (D.P. Berry).

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programmes warrant investigation as well as how such strategies relate to actual BCS assessed.

Linear-type classification is a method of describing the biological extremes for a range of visual characteristics of dairy cows. It is being used ubiquitously in registered dairy cows globally. Angularity is a measure of the 'angle and openness of the ribs, combined with flatness of bone' (https://www.icar.org/Guidelines/05-Conformation-Recording.pdf); BCS and angularity are strongly (antagonistically) correlated (Berry et al., 2004). The measurement of both BCS and angularity is based purely on visual assessment, and, in most instances, the linear assessment used in genetic evaluations is only taken once during an animal's lifetime, predominantly in first lactation. How estimates of genetic merit for these visual assessments of BCS and angularity in first parity cows relate to BCS lactation profiles measured using both tactile and visual assessments in commercial cows has never been quantified. The objective of this study is to fill this void.

Material and methods

All cattle data used in the present study were extracted from the Irish Cattle Breeding Federation (http://www.icbf.com) database. These data included both phenotypic data and estimates of genetic merit stored as predicted transmitting abilities (**PTAs**). The genetic evaluation for linear type traits in Irish dairy cows is undertaken using a multitrait model for Holstein-Friesians which is also used to derive estimates of the associated reliability of each. The PTAs and their respective reliability for BCS and angularity were extracted for the November 2020 national genetic evaluation; phenotypic linear scores from a total of 246 870 cows were included in the evaluation. Linear assessment of BCS and angularity in Ireland (and elsewhere) is undertaken on a 1 to 9 scale where 1 represents thin and coarse for BCS and angularity, respectively, with 9 representing fat and angular, respectively. All data originate from only first-parity cows assessed in the first 305 days of lactation. Differences between classifiers in their range of scoring are accounted for by pre-adjusting each of the type traits prior to the genetic evaluation by the ratio of the standard deviation of each classifier to the mean of the standard deviation calculated for each classifier for that trait in that year as outlined by Brotherstone (1994). Fixed effects included in the national genetic evaluation model are herd date of scoring, age at scoring (quadratic effect), stage of lactation (quadratic effect), calendar month of calving, heterosis coefficient and recombination loss coefficient. Animal is included as a random effect in the model with a genetic and residual variance of 0.400 and 1.807 units^2 for BCS and 0.346 and 0.877 units^2 for angularity, respectively. Prior to publishing, the PTAs are individually re-scaled to have a variance of one. The actual standard deviation of BCS and angularity used in the rescaling are 0.519 and 0.716 units, respectively. Only cows with a reliability of >20% for both traits were considered further.

Phenotypic BCS data were available on 47 293 Holstein-Friesian cows assessed between the years 2000 and 2020 from a range of different parities and stages of lactation; all contributing herds had at least 50 BCS records. BCS was assessed on a 1 (emaciated) to 5 (obese) scale (Edmonson et al., 1989). Only data from parities 1 to 15 were retained and the cows had to be on the farm for at least 100 days prior to assessment. The lactation was stratified into seven stages of 0 to 49, 50 to 99, …, 250 to 299 and 300 to 365. Parity was collapsed into 1, 2, 3, 4, 5+. Contemporary group was defined as herd-year-season of calving developed using an algorithm used for most of the genetic evaluations in Ireland (Berry et al., 2013); only contemporary group with at least 10 records were considered further where the difference in calving date between the start and end of the contemporary group was no longer than 30 days. Cows within contemporary group were stratified into four equal (where possible) groups separately based on PTA for BCS or angularity. The final data set consisted of 58 440 BCS records from 48 823 lactations in 38 608 cows residing in 448 herds; a total of 167 assessors contributed to the edited data set. A subset of this data set was taken which included only 15 318 cows (recorded just once each) from 135 herds assessed by two trained technicians harmonised off each other.

Statistical analyses

The association between PTA for either BCS or angularity with phenotypic BCS (dependent variable) was determined using mixed models with cow lactation included as a random effect in the model, the exception was when the data were limited to the two technicians where a fixed effects model was used as no repeated records existed. Fixed effects included in all models were contemporary group of calving, herd-date of scoring, parity, stage of lactation and the two-way interaction of stage-by-parity. BCS or angularity PTA was included as either a continuous or a class effect in all models as well as in two -way interactions with parity and stage of lactation; the three-way interaction between parity, stage of lactation and genetic merit for either BCS or angularity did not improve the fit to the data.

Results and discussion

Across all data, the linear regression coefficient of phenotypic BCS on PTA for BCS and angularity was 0.08 (SE = 0.0017) and −0.09 (SE = 0.0021), respectively. The partial correlation between phenotypic BCS (after adjusting for all fixed and random effects in the model except for genetic merit) with PTA for BCS and angularity was 0.13 and −0.10, respectively, both of which differed ($P < 0.001$) from zero. When the data were limited to just the two technicians, the respective linear regression coefficients on PTA for BCS and angularity were 0.10 (SE = 0.0032) and −0.11 (SE = 0.0043). When based on just the two BCS technicians, the partial correlation between phenotypic BCS with PTA for BCS and angularity was 0.22 and −0.17, respectively, both of which were different ($P < 0.001$) from zero. The mean phenotypic BCS by stratum of PTA for BCS or angularity is shown in Table 1 for the entire data set; the same trend was detected when the data were just limited to the BCS data scored by the two technicians. Clearly, the estimates of genetic merit for either BCS or angularity (assessed visually on a 1 to 9 scale by professional classifiers on registered primiparous cows) were able to differentiate commercial multiparous cows for BCS scored predominantly by producers on a 1 to 5 scale using both visual and tactile approaches. While training material is provided to producers on how to score body condition, variability in scoring among producers is still likely to exist; some of this mean producer bias in scoring should be accounted for through the stratification of cows on genetic merit within contemporary group (which includes herd) but also the fitting of contemporary group and herd-date of scoring as effects in the statistical model. The existence of such random variability in scoring and its impact on the association with genetic merit was substantiated by the fact that the association between genetic merit for BCS or angularity with phenotypic BCS strengthened when the analyses was limited to two technicians who were harmonised against each other. Despite angularity and BCS scored by the professional classifiers reflecting (subtly) different cow characteristics, a phenotypic and genetic correlation between both traits of −0.61 and −0.84, respectively has been reported (Berry et al., 2004). Therefore, a relationship between genetic merit for angularity with phenotypic BCS is expected, corroborated by the results from the present study.

While mean differences in BCS by genetic merit stratum were evident across the entire data, the association between PTA for either BCS or angularity with phenotypic BCS differed ($P < 0.001$) both by parity and stage of lactation. When based on the entire data set, the linear regression coefficients of phenotypic BCS on PTA for BCS across parities varied from 0.067 (parity 1) to 0.099 (parity 4) and across stages of lactation varied from 0.062 (<50 days in milk [DIM]) to 0.089 (250 to 299 DIM). The regression coefficients of phenotypic BCS on PTA for

Table 1
Number of records (N), mean (SD) predicted transmitting ability (PTA in SD units) and mean (SE) phenotypic (Pheno) body condition score (scale 1 to 5) for dairy cows stratified on PTA for body condition score or angularity.

Stratum	Body condition score			Angularity		
	N	PTA (SD)	Pheno (SE)	N	PTA (SD)	Pheno (SE)
Very high	13886	1.37 (0.55)	3.02 (0.005)	13892	−0.17 (0.46)	2.91 (0.005)
High	14683	0.77 (0.42)	2.97 (0.004)	14669	−0.58 (0.43)	2.94 (0.005)
Low	14580	0.38 (0.39)	2.95 (0.004)	14626	−0.9 (0.46)	2.97 (0.005)
Very low	15291	−0.16 (0.46)	2.91 (0.004)	15253	−1.38 (0.55)	3.01 (0.005)

angularity across parities varied from −0.114 (parity 4) to −0.075 (parity 1) and across stages of lactation varied from −0.101 (250 to 299 DIM) to −0.070 (<50 DIM). A similar range in estimates of regression coefficients was obvious when the data were limited to just the two BCS technicians, although the magnitude of the coefficients was stronger; the regression coefficients of phenotypic BCS on PTA for BCS varied from 0.09 to 0.12 across parities and from 0.09 to 0.14 across stages of lactation while the respective ranges for PTA for angularity were −0.14 to −0.10 and −0.15 to −0.11. The BCS least squares means for the different strata of PTA for BCS or angularity by parity and stage of lactation are illustrated in Figs. 1 and 2, respectively. Although a statistically significant interaction was evident for both parity and stage of lactation, the actual biological significance of the interaction was of little consequence. Hence, genetic merit for either BCS or angularity has, biologically, a relatively similar association across all stages of lactation and life.

Practical relevance

The importance of BCS as both a phenotypic and genetic risk factor for reproductive performance is well established (Pryce et al., 1998; Berry et al., 2003; Roche et al., 2009). However, awareness of the importance of reproductive performance has intensified, resulting in a broadening of dairy cow breeding goals to include reproductive traits (Cole and VanRaden, 2018) contributing to a year-on-year improvement in genetic merit (Berry et al., 2014), achieved by both a growth in phenotype recording for reproductive performance but also the establishment of genomic evaluations. This obviously lessens (not alleviates) the benefit of BCS as a genetic predictor of reproductive performance. Nonetheless, BCS is also (phenotypically and genetically) associated with animal health (Pryce et al., 1998; Roche et al., 2009) and general robustness, both of which are more difficult to fully capture in breeding programs. Moreover, BCS in itself has a direct economic value due to its association with lactation length in seasonal calving herds (Byrne et al., 2013). Hence, BCS as a trait in genetic evaluations remains important.

While relationships between phenotypic BCS and genetic merit for either BCS or angularity do exist, and these relationships persist across parities and stage of lactation, the estimated relationships are not strong. Strong relationships are, however, not necessarily expected. First, the exercise undertaken in the present study is between genotype and phenotype and the maximum strength of this relationship is a function of the heritability. The heritability of BCS and angularity used in the Irish national genetic evaluations is 0.18 and 0.28, respectively. Therefore, a strong correlation cannot be achieved. Second, the reliability of the PTAs for the cows used in the present study is not one; in fact, the mean reliability of the cows in the data set was 0.46 for both linear type traits. Third, errors will exist, not only in the professional scoring of the registered cows for BCS and angularity but probably more so for BCS in the commercial cows scored by a total of 167 different producers.

Furthermore, mean BCS differences by genetic merit presented in the present study are based on a selection of the national population with the stratification of cows for genetic merit being within contemporary group. What is of greater interest is the mean expected differences of cows where more exaggerated genetic diversity may exist, as would be the case in a larger population. Based on a Gaussian distribution with a standard deviation of 1 (i.e., the PTAs in the present study), the difference in mean genetic merit between the top and bottom 10% is 3.51 standard deviation units; if comparing the mean of the top and bottom 20%, this difference is 2.80 standard deviation units. Therefore, based on the estimated regression coefficient of phenotypic BCS on PTA for BCS from the entire data set (i.e., 0.08), the mean expected difference in phenotypic BCS on a scale of 1 to 5 is 0.28 and 0.22 BCS units if comparing the top and bottom 10% or the top and bottom 20% genetically, respectively; if comparing the top and bottom percentiles on PTA for

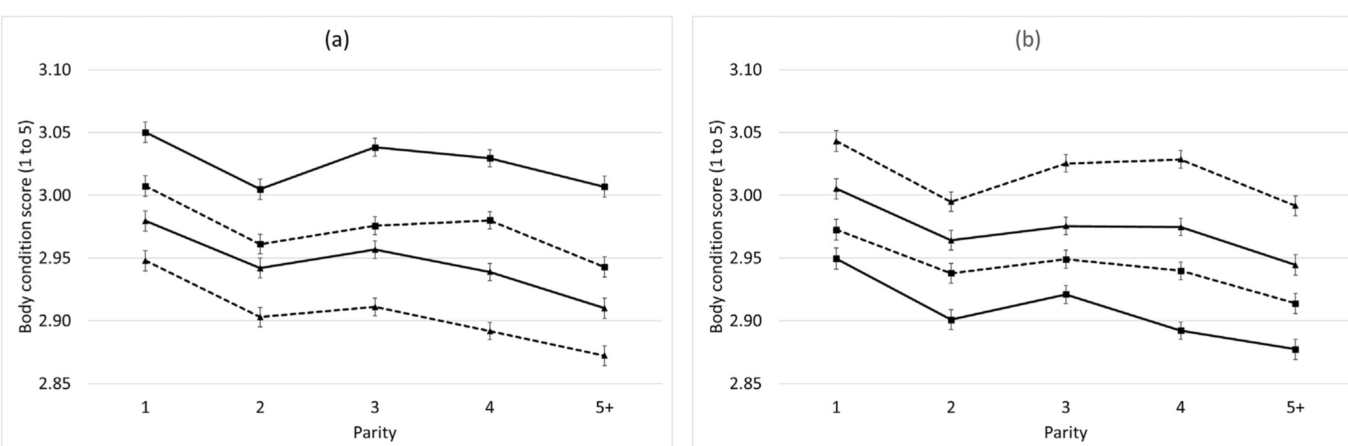

Fig. 1. Least squares mean (one SE each side of the mean) phenotypic body condition score per parity where dairy cows are stratified on genetic merit for (a) body condition score or (b) angularity as very high (—■—), high (---■---), low (—▲—) and very low (---▲---).

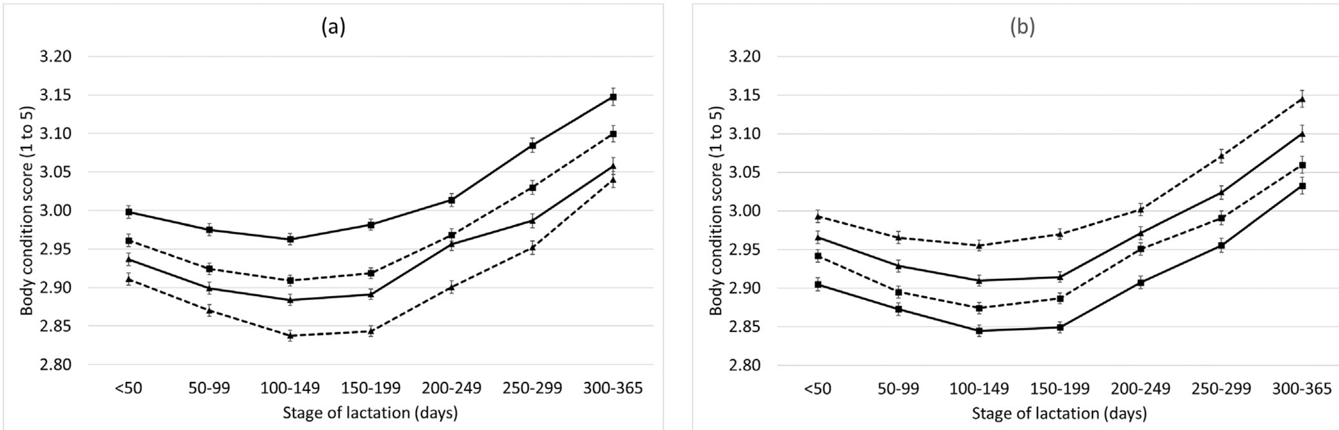

Fig. 2. Least squares mean (one SE each side of the mean) phenotypic body condition score per stage of lactation where dairy cows are stratified on genetic merit for (a) body condition score or (b) angularity as very high (—■—), high (---■---), low (—▲—) and very low (---▲---).

angularity, the respective values are 0.31 and 0.25 BCS units, respectively. These values are similar to that achieved if the estimates from the model treating PTA for BCS (or angularity) as a class effect (Table 1) is extrapolated out to comparing the top and bottom 10% or top and bottom 20%.

Results from the present study clearly provide confidence in the fact that a single BCS or angularity assessment in primiparous cows based solely on visual assessment is useful to breed for cows of better body condition (as producers are more familiar with), irrespective of stage of lactation or parity. While such single point-in-time measures are therefore useful for genetic evaluations, this frequency of measures would not be sufficiently useful for management purposes since it is mostly BCS change (i.e., requires at least 2 measures) which is most important for management purposes (Roche et al., 2009).

Ethics approval

Data used in the present study were available from a pre-existing database.

Data and model availability statement

None of the data were deposited in an official repository.

Author ORCIDs

Donagh P. Berry: 0000-0003-4349-1447. M. M. Kelleher: 0000-0002-7799-941X.

Author contributions

D.P. Berry secured the research funding, helped develop the research question, undertook the association analyses and drafted the manuscript. M.M. Kelleher also helped develop the research question, undertook the genetic evaluation and helped draft the manuscript. Both authors read and approved the final version of the manuscript.

Declaration of interest

The authors report no conflicts of interest with any of the data presented.

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References

Berry, D.P., Buckley, F., Dillon, P.G., Evans, R.D., Rath, M., Veerkamp, R.F., 2003. Genetic parameters for body condition score, body weight, milk yield, and fertility estimated using random regression models. Journal of Dairy Science 86, 3704–3717.

Berry, D.P., Buckley, F., Dillon, P.G., Evans, R.D., Veerkamp, R.F., 2004. Genetic relationships among linear type traits, milk yield, body weight, fertility and somatic cell count in primiparous dairy cows. Irish Journal of Agricultural & Food Research 43, 161–176.

Berry, D.P., Kearney, J.F., Twomey, K., Evans, R.D., 2013. Genetics of reproductive performance in seasonal calving dairy cattle production systems. Irish Journal of Agriculture and Food Research 52, 1–16.

Berry, D.P., Wall, E., Pryce, J.E., 2014. Genetics and genomic of reproductive performances in dairy and beef cattle. Animal 8, 105–121.

Brotherstone, S., 1994. Genetic and phenotypic correlations between linear type traits and production traits in Holstein-Friesian dairy cattle. Animal Production 59, 183–187.

Byrne, T.J., Santos, B., Amer, P.R., Bryant, J.R., 2013. The economic value of body condition score in New Zealand seasonal dairying systems. Proceedings of the Association for the Advancement of Animal Breeding and Genetics 20, 479–482.

Cole, J.B., VanRaden, P.M., 2018. Possibilities in an age of genomics: the future of selection indices. Journal of Dairy Science 101, 3686–3701.

Edmonson, A.J., Lean, I.J., Weaver, L.D., Farver, T., Webster, G., 1989. A body condition scoring chart for Holstein dairy cows. Journal of Dairy Science 72, 68–78.

Ferguson, J.D., Azzaro, G., Licitra, G., 2006. Body condition using digital images. Journal of Dairy Science 89, 3833–3841.

Hansen, M.F., Smith, M.L., Smith, L.M., Abdul Jabbara, K., Forbes, D., 2018. Automated monitoring of dairy cow body condition, mobility and weight using a single 3D video capture device. Computers in Industry 98, 14–22.

Pryce, J.E., Esslemont, R.J., Thompson, R., Veerkamp, R.F., Kossaibati, M.A., Simm, G., 1998. Estimation of genetic parameters using health, fertility and production data from a management recording system for dairy cattle. Animal Science 66, 577–584.

Roche, J.R., Friggens, N.C., Kay, J.K., Fisher, M.W., Stafford, K.J., Berry, D.P., 2009. Body condition score and its association with dairy cow productivity, health and welfare. Journal of Dairy Science 92, 5769–5801.