Results of the Pilot Study for Body Condition Score and Locomotion

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Introduction

On modern dairy farms, traits relating to health and ease of management are of great importance. Two such traits are body condition score and locomotion. Body condition score (BCS) is an important way to monitor body fat resources and, therefore, has been recognized as a good predictor of a cow's energy balance. Locomotion is a measure of how easily a cow walks, which is especially important in free stall barns, where cows need to walk between feed troughs, milking parlor, and resting areas.

The aim of this pilot study is to prepare the stage for an international genetic evaluation of locomotion and body condition score at the Interbull level. Ideally, each country should define these traits similarly. However interest in a measure of a cow's BCS and her ability to walk is not a new idea. Several countries have already developed several measures to provide their farmers this information. Therefore, an important area in the development of international genetic evaluations is the identification of similar traits and potential harmonization of trait definitions.

Inspection of the genetic correlations amongst countries allows one to evaluate the degree of trait similarity. Until now, most efforts have relied upon visual inspection. Hierarchical clustering allows one to group items into different categories. For example, a category may be those countries with a similar trait definition. This study will illustrate how hierarchical clustering may be used to help interpret a matrix of across country genetic correlations and provide a path to trait harmonization or at least a better understanding of what each country is measuring.

Material and Methods

1. National Data

Requests were made to all countries and breeds to submit national genetic evaluations for a test run to evaluate the feasibility of two new conformation traits, as well as, the Form GE and appendix CO (BCO) with the trait definitions. Countries were free to send in traits that best described BCS and Locomotion.

In each trait group, at least two different measures were provided. For example, in Table 1, five countries provided data labeled as BCS and four countries provided data labeled as angularity. The trait angularity is one of the current Interbull traits. It is a visual measure of a cow's appearance to produce milk. Three measures of locomotion were submitted, the direct measure, where the cow's movement is assessed while she is walking. Two indirect measures were provided. Feet & leg score where the appraiser must assess the cow's ability to walk based upon her conformation and may not actual observe the cow walking. Bone quality is an indirect measure of mobility, where more refinement or freedom from thick cartilage is related to better mobility.

2. Genetic Correlations

National evaluation were de-regressed, and REML methodology used to obtain across country genetic correlations and multi-trait across country breeding values using the software of Klei, 1998 and Klei & Weigel, 1998.

3. Hierarchical Clustering

Hierarchical clustering (hclust in R, http://www.r-project.org/) was used to visualize the similarity in trait definitions being applied by different countries. Hierarchical clustering is based on classifying, or partitioning, groups of countries so that countries in each group/cluster are similar based on a distance measure.

For our application we used $d_{ij} = 1-r^2_{ij}$ as the distance measure between countries i and j where r^2_{ij} is the square of the across country genetic correlation. Small values for d_{ij} indicate that the country i and j used similar definitions (large correlation) while large values for d_{ij} indicate large differences in trait definitions (small correlations).

In our study, the input matrix, i.e. the genetic correlation matrix among countries was modified for analysis. All diagonal elements were set to 1.0 and the off-diagonal elements were the absolute value of the genetic correlations between countries.

Clustering techniques have been applied to a wide variety of research problems. In the study of genetic markers, the value r^2_{ij} is frequently used as a measurement of linkage disequilibrium. Similarity between groups of SNPs (single nucleotide polymorphisms) can be determined by examining the cluster plots of SNPs and interpreting the break points ($1 - r^2_{ij}$) as a measurement of which SNPs are similar or dissimilar.

Results and Discussion

The objective behind the measurement of an animal's condition is to quantify the amount of body fat or energy reserve. Two main traits, BCS and Angularity, are being employed for this purpose by the different countries for the Holstein breed (Table 1).

Table 1. Definitions provided by each country.

Country	Trait
BEL - Belgium	**BCS**
CHE - Switzerland	**BCS**
DEU - Germany	**BCS**
DFS – Denmark Finland Sweden	**BCS**
NLD - Netherlands	**BCS**
FRA – France	**Angularity**
FRR – French Red	**Angularity**
ITA - Italy	**Angularity**
USA – United States	**Angularity**

By visual inspection of Table 2, it is clear, by the negative correlations, that FRA, ITA and USA are recording traits differently from the other countries. The cluster dendogram provides a clearer picture. Here we see in Figure 1, that we have at least two main categories. Countries are paired together by the strength and weakness of their correlations. For example, the strongest correlations for the countries, DEU, CHE and NLD were amongst themselves. NLD is correlated with both CHE and DEU at .96. NLD is paired with CHE because they have a stronger correlation with DFS than DEU.

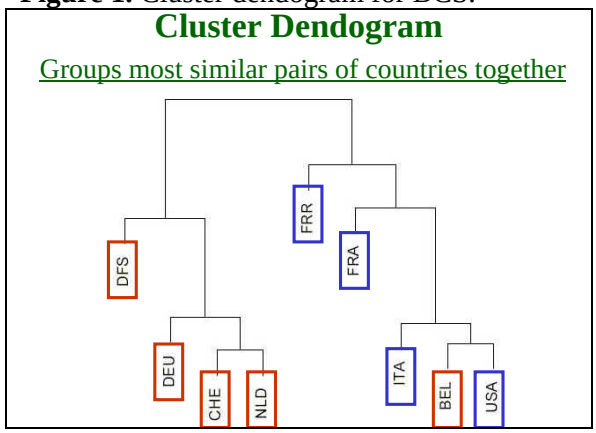
Table 2. Across country genetic correlations for *Body Condition Score* for Holsteins.

Correlation matrix for :: body condition score

	BEL	CHE	DEU	DFS	FRA	FRR	ITA	NLD	USA
BEL	0.15								
CHE	0.90	0.66							
DEU	0.88	0.91	0.33						
DFS	0.72	0.83	0.74	0.17					
FRA	-0.72	-0.56	-0.48	-0.46	0.51				
FRR	0.83	0.71	0.87	0.57	-0.63	0.25			
ITA	-0.92	-0.76	-0.72	-0.64	0.77	-0.71	0.93		
NLD	0.91	0.96	0.96	0.80	-0.52	0.84	-0.78	0.27	
USA	-0.95	-0.76	-0.71	-0.62	0.80	-0.72	0.92	-0.74	1.67

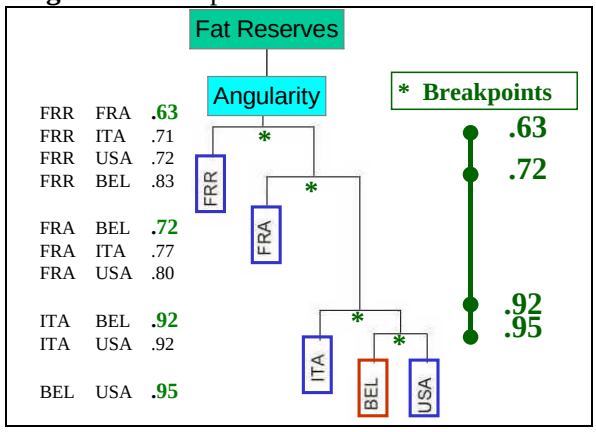
The second group contains close agreement between ITA, BEL and USA. Although FRA and FRR are clustered along with these three countries, its relationship with them is lower. Inspection of the break points (Figure 2.) allows one to interpret the strength of the relationship.

Figure 1. Cluster dendogram for BCS.



The strongest correlation amongst the countries, in the second cluster, is between the pair BEL and USA at .95. ITA follows this pairing with a correlation of .92 to both BEL and USA. The country most correlated to BEL, ITA and USA is FRA. The process continues with FRR being identified as the strongest connection to the four countries. The weakest correlation (or breakpoint) is with FRA at 0.63. As the strength of the relationships decreases, the distance between countries becomes greater and the breakpoints become smaller.

Figure 2. Breakpoints for one cluster of BCS.



Hierarchical clustering points one towards the questions that should be asked about the data structure. For example, why is BCS as recorded by BEL grouped with the countries recording angularity? The answer may be in the fact that the trait is recorded by milk testers, who may be looking at milking potential of a cow. The country group FRR is the least connected with the other angularity countries. Upon further investigation, the trait is actually being recorded as muscularity (opposite scale of angularity). Arguably, FRR could be placed in either category. This provides some support that all countries should be analyzed in one combined analysis. The average correlation amongst the BCS and angularity countries in Table 3 is 0.80.

Table 3. Traits ordered by degree of similarity.

Brings more refinement to trait definitions

Country	Trait	Comments
DEU	**BCS**	**As defined by ICAR**
CHE	**BCS**	**As defined by Edmundson**
NLD	**BCS**	**Relative fatness, composition of cow**
DFS	BCS	
FRR	Muscularity	Opposite of Angularity
FRA	Angularity	
BEL	**BCS**	**Recorded by milk testers**
ITA	**Angularity**	**Breed Association**
USA	**Angularity**	**Breed Association**

The objective behind the measurement of an animal's feet & legs is to quantify their ability to move easily and remain trouble-free. A key consideration in determining the trait definition to be used is whether or not the cows can be observed moving. If a majority of the cows can be observed moving than the preferred measurement is locomotion, which is an actual assessment of how well the cow walks.

Table 4. Definitions provided by each country.

Country	Trait
BEL - Belgium	**Bone Quality**
DFS – Denmark Finland Sweden	**Locomotion**
DEU - Germany	**Locomotion**
GBR – Great Britain	**Locomotion**
FRA – France	**Locomotion**
NLD - Netherlands	**Locomotion**
CHE - Switzerland	**Feet & Leg Score**
ITA - Italy	**Feet & Leg Score**
USA – United States	**Feet & Leg Score**

Primarily, Locomotion and Feet & Leg Scores are being employed for this purpose by the different countries (Table 4).

Table 5. Estimates of across country correlations for *Locomotion* for Holsteins.

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Correlation matrix for locomotion
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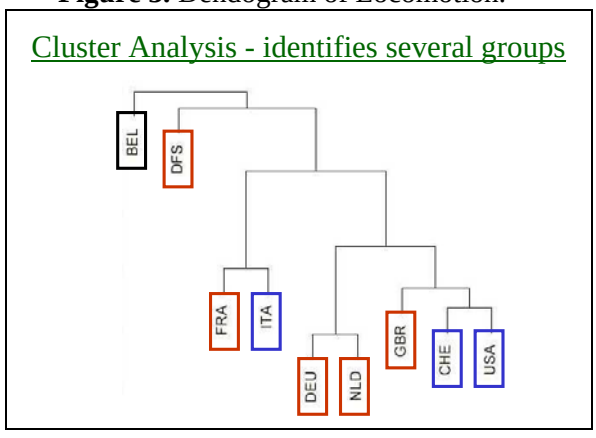
     BEL  CHE  DEU  DFS  FRA  GBR  ITA  NLD USA
BEL
CHE  0.44
DEU  0.35 0.89
DFS -0.11 0.71 0.59
FRA  0.14 0.58 0.76 0.46
GBR  0.49 0.84 0.81 0.44 0.81
ITA  0.33 0.68 0.66 0.45 0.76 0.80
NLD  0.16 0.77 0.90 0.69 0.85 0.79 0.66
USA  0.37 0.87 0.79 0.78 0.75 0.81 0.77 .76
```

Inspection of the correlation matrix shows two countries with low correlations to the other countries. Belgium's trait, bone quality, has a low to moderate relationship with the other feet and legs measures. DFS includes lame cows, so DFS's measure is a reflection of both soundness and mobility (Figure 3.).

Good agreement is found amongst DEU, NLD, GBR, CHE and USA. The country GBR is in a transition from a feet and leg score measurement to a locomotion score. The countries FRA and ITA are an interesting pairing. FRA reports that it's scoring locomotion and ITA reports its scoring feet and legs. Although, they have fairly good agreement between themselves, r_{ij} = .76, they don't fit in completely with the locomotion group or the feet and leg countries. Table 6 shows the traits ordered by degree of similarity. All countries, with the exception of BEL and DFS, could be evaluated in one single-trait Mace.

Figure 3. Dendogram of Locomotion.



As more traits are considered for inclusion, in international evaluations by Interbull, consideration must be given to the practical aspects of collecting the data. Several countries have commented that feet and leg score is a good measure of locomotion, in particular, when it is difficult to observe the cows walking. Dorothee Boelling of Denmark reported that, "about 40% of all herds are suitable for locomotion scoring". John Connor said that the USA would ask owners if they might see the cows walking. However, he expected less than 50% compliance rate. Jun Kurita of Japan stated, "over 80% of barns are tie-up barns, it is not possible to obtain proper data on locomotion".

Table 6. Traits ordered by degree of similarity.

Country	Trait	Comments
DEU	Locomotion	ICAR – WHFF
NLD	Locomotion	ICAR - WHFF
GBR	Locomotion	.98 Correlation with F&L Score Locomotion & Lameness - now separate
CHE	Feet & Leg	Computed from linear traits
USA	Feet & Leg	Locomotion (if seen) or subjective
FRA	Locomotion	
ITA	Feet & Leg	
DFS	Soundness	Locomotion & Lameness
BEL	Unique	Bone Quality

Conclusions

Clustering is a useful tool to visualize the results from our international genetic evaluations. It provides a way to better understand how different countries are defining their traits. Both pilot traits, BCS and Locomotion are an admixture of a couple of different trait definitions. Further harmonization among countries should be pursued. However, in both cases, a single-trait Mace would be appropriate.

Acknowledgments

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References

Klei, L. 1998. Solving MACE equations. *Interbull Bulletin 17, 3-7.*

Klei, L. & Weigel, K. 1998. A method to estimate crrelations among traits in different countries using data on all bulls. *Interbull Bulletin 17,* 8-14.