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EVALUATION OF BODY MEASUREMENTS OF LIMOUSIN YOUNG BULLS BY PRINCIPAL COMPONENT ANALYSIS

JÁNOS TŐZSÉR[1], NATASA FAZEKAS[2], MÁRTON DEMÉNY[3]*, MÁRTON SZŰCS[3]

[1]Albert Kázmér Faculty of Agricultural and Food Sciences of Széchenyi István University
Department of Animal Science, Mosonmagyaróvár, Hungary
ORCID: https://orcid.org/0000-0002-5632-1765
[2]Hungarian University of Agriculture and Life Sciences, Szent István Campus
Institute of Animal Husbandry, Gödöllő, Hungary
ORCID: https://orcid.org/0009-0002-4184-4616
[3]Association of Hungarian Limousin and Blonde d'Aquitaine Breeders, Budapest, Hungary
email: limousin@freemail.hu, demenymarton@gmail.com

*Levelező szerző/corresponding author

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ABSTRACT

The aim of this study was to analyse how body measurements, live weight and age in young Limousin bulls are interrelated, and what ratio of the phenotype variance can be explained by a group of them, so what traits should be considered in early selection.

Body measures of 8-9 months old Limousin young bulls (n=610) in two consecutive years from 32 Hungarian farms were registered, and their covariance structure was studied by principal component analysis. Two components were defined, explaining 71.58% of the total variance. The first component was composed of live weight and body measures; the second component contained age. Live weight, withers' height and hip height measures had highly definitive effect in the first component. Length of back, width at shoulders, and width at hip bone measurements had lower, but still significant effects. Eigenvalue of the first component had been very high, with 58.36% eigenvalue variance. Only effect of age proved to be highly significant in the second component, with an eigenvalue variance 13.22%. As age contributes less, if correction is needed for transforming results of individuals comparable, then it is advised to be based on live weight. Registered body measurements could be considered together in selection decisions, not needless to take all separately.

Key words: Limousin beef cattle, young bulls, principal component analysis, body measurements

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INTRODUCTION

Linear body measurements provide useful information on the suitability of beef cattle for given purposes (breeding, fattening), as their heritability is usually higher than heritability values of conformations scores. Body measurements in beef cattle – both in *Bos Indicus* and *Bos Taurus* – are proved to be positively correlated (with medium to strong coefficients) with economically important traits (e.g., Gunawan & Jakaria, 2010; Marle-Köster, Mostert, & Westhuizen, 2000; Xu et al, 2022), and there are positive correlations between measures done in pre- and post-weaning ages (Orheruata & Olutogun, 1994). Brown and Shrode (1971) showed by stepwise regression, that various combinations of body measurements and body composition traits explained significantly more variation in average daily weight gain and fat thickness than weaning weight and age alone.
Measurement of beef cattle body dimensions is predominantly conducted through traditional means, employing tape measures and measuring sticks, typically requiring 3–5 minutes per animal (Tőzsér et al, 1995; Ouédraogo et al, 2020). Given the strong correlation between heart girth (chest circumference) and live weight, a specialized measuring tape has been devised, incorporating a reference scale for estimating the animal's body weight (Sales et al, 2009; Abreu, Magalhães, Duayer, Machado, & Silva, 2015). However, direct on-animal measurements can elicit significant stress responses in beef cattle, impacting their well-being, feed intake, and growth, and posing risks for technicians (Augspurger & Ellis, 2002; Petherick, Doogan, Venus & Holroyd, 2009; Li et al, 2022). To mitigate stress factors, modern digital techniques have emerged for non-contact weight measurement, such as utilizing a two-dimensional CCD camera (Kongsro, 2014; Shi, Teng, & Li, 2016) or a three-dimensional camera (Wongsriworaphon, Arnonkijpanich, & Pathumnakul, 2015). Reducing the frequency of measurements also aligns with animal welfare principles.
Principal component analysis provides a method of explaining the covariance structure among a large system of measurements by generating a smaller number of artificial variates, so in the case of body measurements, contrast animals of different sizes and shapes. In this manner, principal components can be used to objectively evaluate variation in body shape and to increase our understanding of structural relationships as an entity, rather than as a series of individual and independent relationships (Brown, Brown, & Butts, 1973). The body conformation of Kankrej cows was explained by factor analysis (Pundir, Singh, & Dangi, 2011). In addition, traits that are not selected usually directly, could be included in the principal components. The principal components can be considered new composite traits. In practical terms, these new traits would be used as selection criteria to achieve a particular breeding objective (Boiligon et al, 2016). Therefore, factor analysis explores the relationships among body conformation traits, and as a consequence, can reduce the number of variables by combining two or more variables into a single factor, which has biological significance (Xu et al, 2022).
Factor analysis had been used both in dairy and beef cattle – starting in the 1970s – for analysing groups of economically important traits. Nowadays it is also combined with molecular methods, e.g. Lewis et al (2011) utilized it for SNP results in an evolutionary study, Moravčíková, Kukučková, Mészáros, Sölkner, & Kadlečík (2017) used it for modelling natural selection. Boiligon et al (2016) used principal component analysis (PCA) not only on measured traits but on estimated breeding values of nine weaning and yearling traits in Nelore cattle. Bonifazi et al (2022) estimated breeding

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values by genomic selection based on a large international dataset of weaning weights in Limousin cattle. PCA was also utilized for analysing productive and reproductive traits of Holstein cattle (Castano et al, 2013) and of Red Sindhi dairy cattle breed (Mello et al, 2020). Results of two analyses on Holstein-Friesian and Hungarian Fleckvieh cows by PCA (Tőzsér et al, 2001) clearly confirmed that the variables for the deposition of fat and adipose tissue cellularity have to be included in the prediction model. Tőzsér et al (1997) evaluated the results of the performance test in Limousin breeding candidates by this statistical method. Also factor analysis was applied to studying the chances for infectious disease in cattle populations, such as determination of the early detection of mastitis and lameness in dairy cows (Miekley, Traulsen, & Krieter, 2013) and of the incidence of diseases in Norwegian Red Cattle (Zarnecki et al, 1985).
Factor analysis was also applied previously for studying the relationship between conformation scores and body measures. In one of the earliest PCA analyses on body measures in beef cattle (Hereford and Angus) Brown, Brown, & Butts (1973) investigated nine skeletal measures and body weight at 4, 8 and 12 months of age. At 8 months of age – similar to the young bulls in our present study – the first principal component included measures of general size, while the second one expressed type differences between the two breeds. McCurly and McLaren (1981) studied the same two breeds, and their results are quite similar to the paper cited above. Hammack and Shrode (1986) included weight, subcutaneous fat and visual condition score next to the body measures in a PCA analysis in Hereford and Angus breeds at weaning age (so 230 days old on average). Pundir, Singh, & Dangi (2011) included 18 body measurement traits – not just those related to production – in a factor analysis of a local cattle breed. Their result suggested that principal component analysis could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain body conformation. Fischer, Luginbühl, Delattre, Delourad, & Faverdinl (2015) found an important source of variance of body condition by it in Holstein dairy cows, while Putra, Said, & Arifin (2020) showed that this statistical method is useful in describing the body measurements and body indices in the Pasundan cows. Tőzsér et al (2000a) used PCA for investigation of conformation traits of weaned Charolais calves in Hungary.
Based on the findings mentioned above regarding the advantages of principal component analysis, the aim of this study was the characterization of body measurement parameters of Limousin young bulls in Hungarian nucleus farms, and explore the possible role of body measurements in early selection.

MATERIAL AND METHOD

For the study the body measures of 8-9 months old Limousin young bulls (n=610), in two consecutive years (2021: n=117, 2022: n=493), in 22 Hungarian farms were registered. Data collection had been countrywide, involving all nucleus breeding stations. Number of animals by farms varied between 5 and 135.
Since 2021, the Association of Hungarian Limousin Cattle Breeders revised its breeding program. As part of this revision, body measurements of young Limousin bulls were conducted across various nucleus farms in Hungary. Skilled technicians performed these measurements using standardized equipment under suitable conditions, including a plain concrete floor and securing the animals in a corridor (*Table 1*).

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Table 1 Methods for taking body measurements

Body measurement	Measuring points	Equipment
Withers height	Horizontal distance between the ground and the withers	Measuring stick
Tail height	Horizontal distance between the ground and the hip bone	Measuring stick
Length of back	Distance between the withers and the loin	Tape measure
Width of shoulders	Width at the widest point of the withers	Measuring stick
Width at hip bone	Distance between the two points of hip	Measuring stick
Pin width	Distance between the two ischium	Measuring stick

Statistical analysis was performed using the SPSS 24 (SPSS Inc., Chicago, IL) statistical software. Salient values (±3xIQR) were removed from the database. Principal component analysis is a statistical method for data compressing and revealing the structure of data. It groups the starting variables and compresses them into factor variables, which directly can't be recorded. There're no previously appointed dependent and independent variables in this method, but it aims to explore the interrelation of the variables. Principal component analysis investigates the relationship of several variables, which are correlated to each other. Background variables were calculated from the correlation matrix of the parameters.

Measures of Sampling Adequacy (MSA) were the following by variables: age (0.75), live weight (0.92), height at withers (0.81), tail height (0.80), length of back (0.92), width at shoulders (0.92), width at hip (0.90), pin width (0.92). This means that all of these variables are strongly connected to each other. Anti-image correlations were mostly very loose, between -0.76 – 0.07, which is favourable for this kind of analysis. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.875, suggesting that our data is suitable for principal component analysis (KMO≥ 0.8).

Rotation of factors (Eigenvalues >1) was done as outlined by the Varimax with Kaiser normalization (Sváb, 1979).

RESULTS AND DISCUSSION

Mean values of the body measures and standard deviations are shown in *Table 2*. The CV% values of the body measurements were less than 11%, so it can be said that our data are homogeneous. In previous years, the body measurement data of the calves – which could help the selection decision after weaning – were not available in Hungary for the Limousin breed.

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Table 2 Descriptive statistics of Limousine young bulls

Parameters	Mean	Std. Deviation	cv%	SE
Age (days)	283.7	113.40	39.9	4.59
Live weight, LW (kg)	242.4	51.54	21.3	2.09
Withers height, WH (cm)	105.7	4.64	4.4	0.19
Tail height, HT (cm)	111.7	5.39	4.8	0.22
Length of back, LB (cm)	68.7	5.46	7.9	0.22
Width at shoulders, WS (cm)	20.5	2.13	10.4	0.09
Width at hip bone, WHB (cm)	32.5	3.12	9.6	0.13
Pin width, PW (cm)	11.7	1.10	9.4	0.04

Tőzsér et al (2000a) analysed body measures of 6-7 months old young bulls (n=83) in Charolais nucleus farms. The following body measures were recorded after weaning: withers height (101.8±4.49 cm), heart girth (138.9±6.92 cm), chest depth (45.8±3.58 cm), diagonal body length (120.1 ±6.10 cm), scrotum circumference (19.8±2.47 cm). As Charolais young bulls in the mentioned study were younger (207 days old) than Limousins in the present one, their height at withers was also a bit lower.

Analysing the value of communalities is important in applying principal component analyses (*Table 3*). These values show to which extent (percentage) all principal components used in the study define a given parameter. Data were well-defined (0.583-0.928) in case of AGE, a LW, WH, HT, LB, WS and WHB measures, while less but acceptable (0.532) in case of PW.

Table 3 Communalities of Limousine young bulls

Parameters	Extraction
Age (days)	0.928
Live weight, LW (kg)	0.826
Withers height, WH (cm)	0.791
Tail height, HT (cm)	0.842
Length of back, LB (cm)	0.616
Width at shoulders, WS (cm)	0.583
Width at hip bone, WHB (cm)	0.608
Pin width, PW (cm)	0.532

Two principal components were defined in this study: the first component is live weight and body measures; the second component is age (*Table 4*).

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Table 4 Eigenvalues, explained variance, rotated loadings of Limousine young bulls

Parameters	Components	
	1	2
Age (days)	0.038	*0.963*
Live weight, LW (kg)	*0.909*	-0.012
Withers height, WH (cm)	*0.888*	0.037
Tail height, HT (cm)	*0.917*	0.010
Length of back, LB (cm)	*0.747*	0.242
Width at shoulders, WS (cm)	*0.749*	-0.149
Width at hip bone, WHB (cm)	*0.777*	0.070
Pin width, PW (cm)	*0.699*	0.209
Eigenvalue	4.669	1.058
Variance of eigenvalue, %	58.36	13.22
Total variance explained, %	71.58	

Component loadings in the first component were from 0.699 to 0.917. LW, WH and HT measures had a highly definitive effect (component loads ≥0.888) in the first component. LB, WS, and WHB body measures had lower but still significant effects (component loads ≥0.747). The less definitive was the PW (component load =0.699) in the first component. Eigenvalue of the first component had been very high, with 58.36% eigenvalue variance. Results show that live weight and both height measures had the most determinative effect on forming the first component.

Only the effect of age proved to be highly significant (0.963) in the second component (age). Component loads in all other traits were between -0.149 and -0.242, so had only a very slight effect on second principal component. The eigenvalue of the second component was 1.058, with a relatively high (13.22%) eigenvalue variance. So, the two components defined could explain 71.58 of the total variance of the studied body measurements in young bulls.

Body measures of Limousin calves have not been studied in Hungary so far. Age, live weight and body measures of Charolais cows were analysed by cluster analysis in Tőzsér et al (2000b). The dendrogram clearly showed that age was separated from all other parameters studied. Therefore, age separating from body measures was also proved by cluster analysis, next to the factor analysis in the present study. Also, in Charolais breed, Tőzsér et al (2000a) could separate the following factors (background variables) after Varimax rotation by factor analysis: I. live weight-body measures (variance: 3.86, explaining ratio: 38.7%); II. muscularity-condition (variance: 2.32, explaining ratio: 23.3%); III. age-scrotum circumference (variance: 1.60, explaining ratio: 16.0%). These three factors together could explain 78% of the total variance. These values are slightly higher than those we report in the present study.

In Hereford and Angus bulls of the same age, PC1 – including general size measures – explained 68% of the variance, and PC2 contrasting tall, narrow bulls with short, wide-bodied ones approximately 10% (Brown, Brown, & Butts, 1973). In the same two breeds, but in cows and calves, the first principal component also contained general size measures, and meant 56.2% and 46.9% of the phenotype variance. PC2 contained positive coefficients for weight and height and negative ones

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for length, depth and fat thickness, so contrasted animals according to body shape, accounted for an additional 20.3% of the original variation. The total variation explained by the first two principal components was 72.5 and 67.2% for cows and calves (McCurly and McLaren, 1981). According to Hammack and Shrode (1986), in Hereford and Angus, at weaning, the first principal component was a measure of overall size, accounting for 66 to 69% of the total variation. It provided a means of contrasting animals according to overall size and fatness because all coefficients were positive. Animals with large positive values for PC1 would tend to be above average for all traits, with the reverse being true for individuals with large negative values. Principal component 2 was mainly a contrast of animals in high condition, narrow at the hips and short-bodied, with those that were thin-fleshed, long-bodied, wide individuals. Xu et al (2022) in dual purpose Simmental found that among factors with eigenvalues ≥ 1, F1 was mainly related to body frame, muscularity, and rump; F2 (8.13% variability) was related to feet and legs; F3, F4, F5, and F6 were related to teat placement, teat size, udder size, and udder conformation; and F7 was related to body frame. These analyses suggest that a few factors can describe a variety of body conformation traits without reducing the accuracy of genetic assessments.
Taking body measures after weaning provides more information (next to ancestry, birth weight, weaning weight and age) to the breeder for carefully planned selection decisions. Weaning and yearling body measures in Hereford were analysed by Marle-Köster, Mostert, & Westhuizen (2000), and they showed that this breed increased in South Africa from an average of 119.38 cm to 129.54 cm in 15 years when breeders started to use hip height measurement next to weight.
Recording body measures in young animals is verified by researches founding correlations between body measures at weaning and after maturing. (Brown & Shrode, 1971; Gunawan & Jakaria, 2010; McCurly & McLaren, 1981; Orheruata & Olutogun, 1994). It makes sense to think about correcting body measures even in case of young animals when analysing body measure data.

CONCLUSIONS

Limousin breeders in Hungary could rely only on ancestry, health status, age and live weight in selection decisions for decades. Registering the body measures of young animals gives additional pieces of information in breeding, can serve bases for adequate decisions (which animals to be sent for farm or central self- performance tests, which animals better send for fattening, which ones to sell), therefore introducing them in breeding plan had been a significant step.
As a comparison, Hungarian Charolais Breeders Association applies the conformation scoring system (muscularity, bone structure development, breed character and others) developed by the French Institut d'Elevage (Magyar Charolais Tenyésztők Egyesülete, 2023). In case of other beef breeds in Hungary (Hereford, Angus, Hungarian Fleckvieh) there is no conformation judgement for young animals.
Tőzsér et al (2000c) analysed body measures of cows of different ages, and suggested correcting possibilities. Correcting based on live weight was suggested in case of height at withers. In the case of heart girth and diagonal body length, correction has to be done based on condition score, rather than taking into consideration nutrition state indirectly. In the present study in young Limousin bulls, the first component defined (live weight and body measurements) with 58.36% eigenvalue variance suggests that correction of the raw data – for making body measures comparable – can be done

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based on live weight in the given farm, applying regression method, for example: WH_{i-corr} cm = WH_i cm ±b (AVE-LW – LW_i).

FIATAL LIMOUSIN BIKÁK TESTMÉRETEINEK ÉRTÉKELÉSE FŐKOMPONENS-ELEMZÉSSEL

ÖSSZEFOGLALÁS

A tanulmány célja fiatal limousin bikák testméretei, élősúlya és kora közötti összefüggések elemzése volt, és annak vizsgálata, hogy a fenotípus varianciák milyen mértékben befolyásolják a vizsgált paramétereket, vagyis mely tulajdonságokat kell figyelembe venni a korai szelekció során.
A testméretek 8-9 hónapos fiatal limousin bikáktól származtak (n=610), melyek 32 magyar törzstenyészetből két egymást követő évben kerültek gyűjtésre. A vizsgálatban főkomponens analízist alkalmaztak. Két főkomponens került meghatározásra, melyek összesen a teljes variancia 71,58%-át magyarázták meg. Az első főkomponens az élő súlyból és a testméretekből állt, a második főkomponens pedig az életkor adataiból tevődött össze. Az élősúly, a marmagasság és a farmagasság eredményeinek volt határozott hatása az első főkomponensben. A háthossz, a marszélesség és a csípőcsont szélesség eredményeinek alacsonyabb, de még mindig szignifikáns hatása volt. Az első főkomponens sajátértéke nagyon magas volt, 58,36%-os sajátérték varianciával. A második főkomponensben csak a kor hatása bizonyult rendkívül jelentősnek, 13,22%-os sajátérték varianciával. Mivel a kor egy kevésbé meghatározó paraméter, ezért, ha az egyedek eredményeinek összehasonlításához korrekcióra van szükség, akkor a korrekcióra az élősúlyt lehet javasolni. A felvett testméreteket együtt lehet figyelembe venni a szelekciós döntésben, nincs szükség mindegyik tulajdonságot külön-külön figyelembe venni.

Kulcsszavak: limousin húsmarha, fiatal bikák, főkomponens analízis, testméret felvételezés

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