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Measurements of healthy and pathologically altered hooves, their interrelation and correlation with body mass in Simmental breeding bulls

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ABSTRACT

The aim of this paper was to determine the standard measures of the hoof (claw): length, height, heel height and hoof surface in breeding bulls as indicators for the correction of hooves. The paper deals with the healthy and pathologically altered hooves of 11 Simmental bulls, owned by the Centre for Reproduction in Livestock of Croatia, Križevci. After measuring these dimensions, their mean values were calculated, and a statistically significant difference was determined between values within each group of parameters and a certain correlation between the mean values and weight of each bull. The average length of the front limb hooves in the bulls studied was 9.39 cm, and the average length of the hind limb hooves was 9.92 cm. The average height of the front limb hooves was 8.65 cm and average height of the hind limb hooves was 8.63 cm. The average height of the front limb hoof heel of the bulls studied was 5.93 cm, and the average height of the hind limb hoof heel was 5.09 cm. The average surface of the front limb hooves was 122.46 cm² and the hind limb hooves 102.49 cm². The degree of correlation between the hoof length and body mass in front limb hooves was fourfold higher than the one in hind limb hooves. The trimming of the front limb hooves was rendered difficult by the live animals' restlessness and the fact that they lean on one front limb hoof which is overburdened by the front part of the body during trimming and the horn of the front limb hooves was much firmer than of the hind limb hooves. A negative correlation between the obtained measurements of the heel height in front and hind limb

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hooves and body mass indicates that the increase in body mass overburdens the legs, and therefore their heel parts. The average surface area of the front limb hooves was 20 percent larger than the surface area of hind limb hooves. A significant and a very high correlation existed for the total area of hooves in relation to body mass of breeding bulls, and this correlation was more pronounced in the hoof surface of the front limb and body weight than the surface of the hind limb hooves and body weight. Hoof area increased with increasing body weight and the degree of correlation was more pronounced in the front limbs than in the hind limbs. This is, most probably, related to the fact that the front limb hooves suffer greater physiological load. The correlation of the total surface area of all limb hooves and body mass was also high.

Key words: breeding bulls, hoof measurements, body weight

Introduction

Raising bovines is an important branch of cattle rearing, primarily because of the production of meat and dairy products. Basic prerequisites for top-quality production are good genetics (the appropriate choice of the breeding stock), the appropriate way of keeping (zoo-hygienic factors, feeding) (BICKERT et al., 1997) and maintaining the animals' health (preventive vaccinations, diagnostic examination, regular check-ups, hoof care) (TOUSSAINT RAVEN, 1985; BLOWEY, 1993; GREENOUGH et al., 1997; STANEK, 1997; DOHERTY, 2005; RADOSTITS et al., 2007).

As is known, common hoof diseases in bovines cause different degrees of lameness, which result in significant production losses (SPRECHER et al., 1997; WARNICK et al., 2001; ANDERSON and DESROCHERS, 2004; DOHERTY, 2005; KOS et al., 2006; RADOSTITS et al., 2007). That is the reason why corrective trimming needs to be carried out regularly, as a routine zoo-technical preventive and therapeutic procedure (TOUSSAINT RAVEN, 1985; WEAVER, 1985; GREENOUGH et al., 1997). In order to carry out the procedure necessary for maintaining the health of the herd, hoof measurements in cows and the relationship between them have been well established (FESSL, 1968; GREENOUGH et al., 1997; KEHLER and SOHRT, 2000; NUSS and PAULUS, 2006). Most hoof horn lesions affect the lateral hooves of the hind limbs. Because of greater weight-bearing (compared with the medial hind hoof) the lateral hoof appears to have a predisposition to disease in cattle kept on hard surfaces (NUSS et al., 2011). In the hind limbs, asymmetry of the paired hooves has been documented (NUSS and PAULUS, 2006) and this difference in hoof size is related to the greater weight-bearing by the lateral hoof (VAN DER TOL et al., 2002). The medial hooves of the forelimbs bear more weight than the lateral hooves (TOUSSAINT RAVEN, 1989; VAN DER TOL et al., 2002), thus the lateral hooves are more commonly affected by sole ulcers (MURRAY et al., 1996). Lesions have been reported to occur more often in the medial than in lateral hooves (RUSSEL et al., 1982, MURRAY et al., 1996), but some lesions, such as vertical fissures, are more common in the lateral forelimb hooves. On the forelimb both hooves are loaded equally during the ensuing phases of the step cycle (VAN DER TOL et al., 2003). It is reported that standardised sole thickness has been

used as a reference measure for the evaluation of other claw variables (FESSL, 1968; NUSS and PAULUS, 2006). Sole thickness contributes significantly to claw integrity and constitutes a critical parameter for foot trimming in cattle as a number of other measures depend on it (NUSS and PAULUS, 2006). Functional foot trimming in cattle has focused on the hind limb hooves (TOUSSAINT RAVEN, 1989; KEHLER and SOHRT, 2000; NUSS and PAULUS, 2006), and publication of measurements of forelimb hooves are limited (NUSS et al., 2011). In contrast, little is known about hoof measurements and their relationships in breeding bulls. The relevance for hooves diseases and hoof trimming of forelimb hooves in finisher bulls has been reported (SIGMUND et al., 2010) and the difference between the measurements of lateral and medial hind limb hooves in young bulls has been published (PAULUS and NUSS, 2006). The importance of timely trimming and maintaining hoof health in breeding bulls is of inestimable value, otherwise orthopaedic diseases occur, fertility is decreased, and body mass and libido are reduced, which leads to lower-grade production and semen quality, and finally results in the inhibition of sexual reflexes (impotence). This is especially important for breeding bulls used for the production of semen in cattle-raising centres, which are of special significance for cattle rearing in every country.

This paper aims at obtaining relevant data using measurements taken of certain dimensions of the hooves, their interrelation and comparison, as well as establishing the correlation between them and the bulls' body mass. The obtained measurements will be used for calculating the ground surface of each hoof and correlated with the body mass of each bull. The subsequent corrective trimming and measuring of healthy and pathologically altered hooves should provide an insight into the standardisation of measurements during corrective trimming with regard to the bull's body mass.

Materials and methods

During the research, 11 Simmental bulls, aged two to nine years, were kept in the stables of the Centre for Animal Reproduction of Croatia, Križevci, Croatia, and were tethered in controlled conditions. The body mass of the bulls ranged from 635-1370 kilograms. Four bulls were without pathological alterations on their hooves. The remaining bulls had varying degrees of expressed alterations on their hooves: 4 bulls had ulcers on their soles (Pododermatitis circumscripta) and 3 bulls suffered from interdigital hyperplasia (Hiperplasia interdigitalis).

The bulls were immobilized with a stationary chute, ropes and chains. The hooves were trimmed with pliers, the excess horn on the soles and in the interdigital space was removed with a knife and final, delicate treatment of all the surfaces was performed with an electric grinder. A calliper was used for measuring the dimensions of the trimmed hooves. The length of the hoof was measured from the border between the skin and the

coronet to the distal end of the dorsal wall and parallel to the digital axis, the height of the hoof was measured from the border between the skin and the coronet to the vertical point of the sole, the height of the heel was measured along a line perpendicular to an imaginary caudal extension of the sole to the highest point of the heel, the diagonal of the hoof was measured from distal end of the dorsal wall to the highest point of the heel, and the width of the hoof was measured along the line intersecting the sole length at its widest part (Fig. 1). The measurements were performed on live animals, so we trimmed the sole to the healthy part of the hoof horn, taking care to avoid injury to the corium. After measuring these dimensions, their mean values were calculated, and a statistically significant difference was determined between values within each group of parameters and a certain correlation between the mean values and weight of each bull.

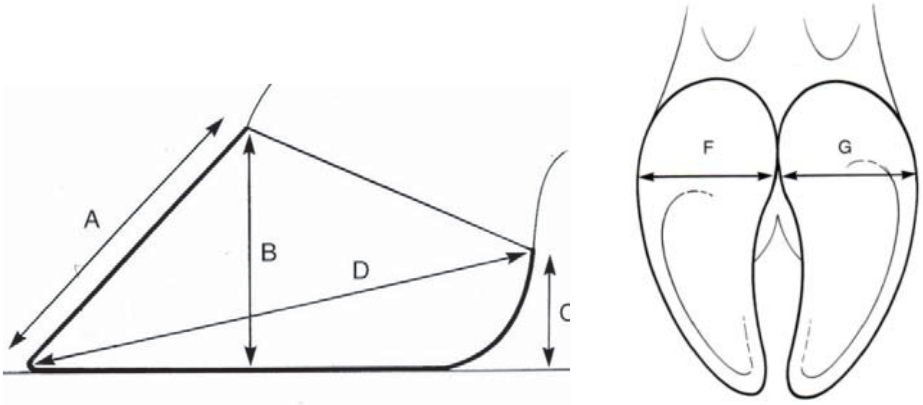


Fig. 1. A- length of the hoof; B-height of the hoof; C-height of the heel; D-diagonal diameter of the hoof; F+G-width of the hoof (GREENOUGH et al., 1997).

Data were evaluated using explorative data analysis and normal distribution was tested with the Kolmogorov-Smirnov test. The means of all values were analysed and a statistically significant difference between values within each group of parameters was determined using the Mann-Withney U test. Differences were considered statistically significant at $P<0.05$. Correlations between hoof length, hoof height, heel height, surface of a digit and body mass were calculated using Spearman's rank test. The software used for statistical calculation was STATISTICA 8.1.

Results

Table 1. The results of measuring hoof dimensions and body mass. A-hoof length; B-hoof height; C-heel height; D-hoof diagonal; F-width of 3rd digit; G-width of 4th digit, F+G-hoof width; m-body mass

	Left front limb											Right front limb										
	3rd digit				4th digit				Soles			3rd digit				4th digit				Soles			
Bulls	A	B	C	D	A	B	C	D	F	G	F+G	A	B	C	D	A	B	C	D	F	G	F+G	m
1	10	10	6.5	17	10	10	8	17	7.5	7.5	16	10.5	9	8.5	17.5	10	9.5	7	17.5	7.5	7.5	17	935
2	9.5	9	5.5	16.5	10	9	6.5	16.5	7	6.5	15	10	8.5	7	15.5	10	9	7	16.5	6.5	7.5	15	1195
3	8	8	5	12	8.5	8	5.5	14	5.5	5	12	8.5	7.5	5	12.5	8	7.5	5	13	5	6	12	635
4	8.5	8	7	16	8.5	9	8.5	15.5	7	7	16	9.5	8.5	6	16	9.5	9	6	16	7.5	7.5	17	1110
5	8	8.5	7	16	8.5	8	7	15.5	6.5	7	14	8.5	8.5	6.5	16	8	8	5.5	15	6	6.5	14	1160
6	11	9.5	4.5	16	10	9	5.5	15.5	6.5	7	14.5	10.5	9	5.5	14.5	10	9	5.5	15.5	6	7.5	14.5	1110
7	9	8.5	5.5	16.5	9	8.5	6	16	7	7	15	10	9	6.5	16	10	9.5	6.5	16	7.5	7.5	16	1060
8	10.5	8	6.5	16	10	8.5	6	16	8	8	17	10	9.5	6	16.5	10	10	6	17	7.5	8	16.5	1170
9	10	9	5.5	15.5	10	8.5	6	16	8	8	17	10.5	10	5.5	15	10	9	5.5	15	7	7.5	16	1370
10	9	8.5	5	16	9.5	8.5	5	16	7	7.5	16	8	8	5	17	8	7.5	4.5	17	8	8	16	1300
11	9.5	8	5	16	9	7.5	4.5	17	8.5	8	17	8.5	7.5	4.5	16.5	9	8	5	16	8.5	7.5	17	1300
	Left hind limb											Right hind limb										
1	10	10	6	16	10	8	5	17	7	6	14	10.5	10	5.5	16	10.5	9	5.5	17	6.5	7.5	16	
2	11	8	4.5	15	11.5	10	7	16	7.5	6.5	14.5	11.5	9.5	6	16.5	11.5	10	6.5	16.5	7	7.5	15	
3	9	7	5	12	9	7	5	12.5	5.5	5	11.5	8	7	4.5	12	8	7.5	4	12.5	5	5.5	11.5	
4	10	8	5.5	14	10	8.5	6	15	6.5	6	14.5	10	9.5	5.5	14.5	10	9.5	5.5	14.5	6.5	6.5	14	
5	8	7.5	4.5	13	8	7.5	4.5	13	6	5.5	13	8.5	7	4.5	13	8.5	7.5	4.5	13	5.5	6	13	
6	11	9.5	5.5	15	11	8.5	5.5	15	6	5.5	13	10.5	9	5	14.5	10	8.5	4.5	15	5.5	6.5	13.5	
7	10	8	4.5	15.5	9.5	8.5	5.5	14	6.5	6	14	11	8.5	5	15	10	9.5	5	14	6	6	13	
8	11	10.5	4	16.5	11	10.5	5	16	8.5	6.5	16	12	10	5	16	10.5	10	5	15	5.5	7.5	15	
9	10.5	10	5	14.5	10.5	10	5.5	15	7	5.5	13.5	10.5	9.5	4.5	15.5	11	10	4.5	15	6.5	6.5	14	
10	8	7	4.5	14	8.5	7.5	4.5	14.5	6	5.5	13	9	8	5.5	14	9	8	5	14	6	5.5	12.5	
11	9.5	8	5	14.5	9.5	8	5	16	7.5	6.5	15	9.5	7.5	5	15.5	10	7.5	5.5	15.5	6.5	7	14.5	

Table 2. Hoof surface calculated using the formula: D X F+G X 0.5; D-hoof diagonal; F+G-hoof width

	Hoof surface (cm^2)											
	Left front limb			Right front limb			Hind left limb			Hind right limb		
Bulls	3rd digit	4th digit	Mean	3rd digit	4th digit	Mean	3rd digit	4th digit	Mean	3rd digit	4th digit	Mean
1	136	136	136	144.5	144.5	144.5	112	119	115.5	128	136	132
2	123.75	123.75	123.75	116.25	123.75	120	108.75	116	112.375	123.75	123.75	123.75
3	72	72	72	75	78	76.5	69	71.87	70.435	69	71.87	70.435
4	128	124	126	136	136	136	101.5	108.75	105.125	101.5	101.5	101.5
5	112	108.5	110.25	112	105	108.5	85.5	85.5	85.5	84.5	84.5	84.5
6	112	112.37	112.185	105.12	111.37	108.745	97.5	97.5	97.5	97.87	101.25	99.56
7	123.7	120	121.85	128	128	128	108.5	98	103.25	97.5	91	94.25
8	136	136	136	136	140.25	138.185	132	128	130	120	112	116
9	131.75	136	133.875	120	120	120	97.87	101.25	99.56	108.5	105	106.75
10	128	128	128	136	136	136	91	94.25	92.625	87.5	87.5	87.5
11	136	144.5	140.25	140.25	136	138.125	108.75	120	114.375	112.37	112.37	112.37

The average length of the front limb hooves in the bulls studied was 9.39 cm, and the average length of the hind limb hooves was 9.92 cm. The average height of the front limb hooves was 8.65 cm and average height of the hind limb hooves was 8.63 cm. The average hoof heel height in the front limb of the bulls studied was 5.93 cm, and average height of the hind limb hooves heel was 5.09 cm. The average surface of the front limb hooves was 122.46 cm^2, and the hind limb hooves 102.49 cm^2 (Table 1, Table 2)

In this research, the correlation between the length of the hoof, the height of the hoof, the height of the heel, the surface area of the hoof, the total surface area of both hooves and the body mass in breeding bulls were examined. By examining the correlation coefficient between the hoof length and body mass in the front and hind limb hooves, it was established that there was a higher degree of correlation in front limb hooves (r=+0.35), where there was a moderate correlation, whereas the correlation between these variables in hind limb hooves was negligible (r=+0.09). (Fig. 2.1., Fig. 2.2.)

There was no correlation between the hoof height and body mass in the front limb hooves (r=0), whereas there was a slight correlation in the hind limb hooves (r=+0.20) (Fig. 3.1., Fig. 3.2.)

There was a negligible and slight correlation between the heel height and body mass in the front limb hooves (r=-0.01), and in the hind limb hooves (r=-0.30) (Fig. 4.1., Fig. 4.2.).

There was a very high correlation between the digital surface and body mass in the front limb hooves, that is (r=+0.75), whereas there was a significant correlation in the hind limb hooves (r=+0.41). (Fig. 5.1., Fig. 5.2.)

In the final correlation outline, it was established that there was a significant correlation between the total surface area of the hooves and the body mass of all bulls (r=+0.57). (Table 4, Fig. 6.)

Table 3. Correlation between hoof length, hoof height, heel height, surface of a digit and body mass

Correlation of tables for front limb hooves	No. of animals N = 11	Correlation of tables for hind limb hooves	No. of animal N = 11
Variables	Body mass (kg)	Variables	Body mass (kg)
Length of the hoof (A)	0.35	Length of the hoof (A)	0.09
Height of the hoof (B)	0.00	Height of the hoof (B)	0.20
Height of the heel (C)	-0.01	Height of the heel (C)	-0.30
Surface area of the hoof (cm^2)	0.75	Surface area of the hoof (cm^2)	0.41

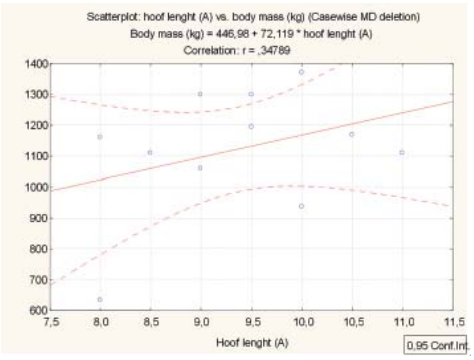


Fig. 2.1.

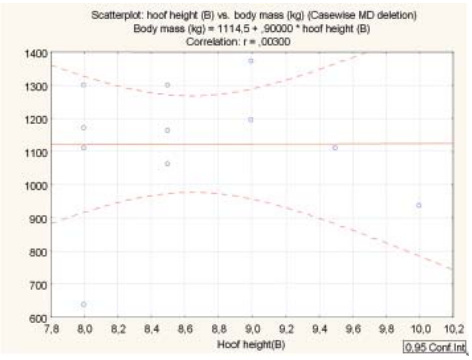
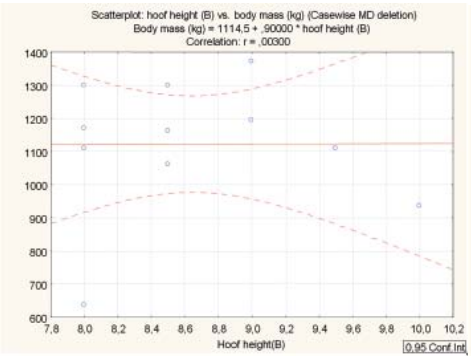


Fig. 2.2.

Fig. 2. Diagrams depicting the correlation between hoof length and body mass in front (Fig. 2.1.) and in hind (Fig. 2.2.) limb hooves



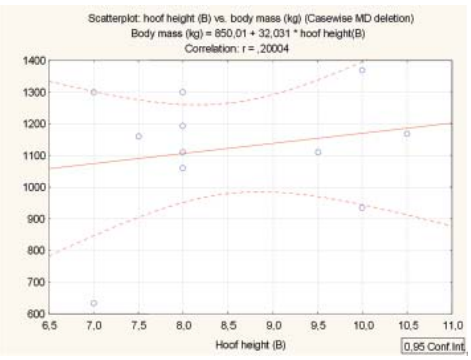
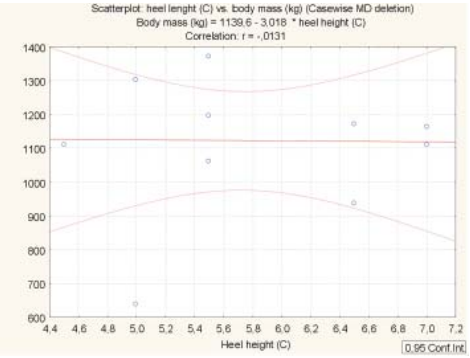


Fig. 3.1. Fig. 3.2.

Fig. 3. Diagrams depicting the correlation between hoof height and body mass in front (Fig. 3.1.) and hind (Fig. 3.2.) limbs



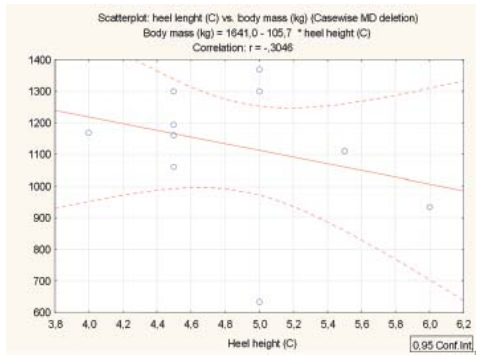
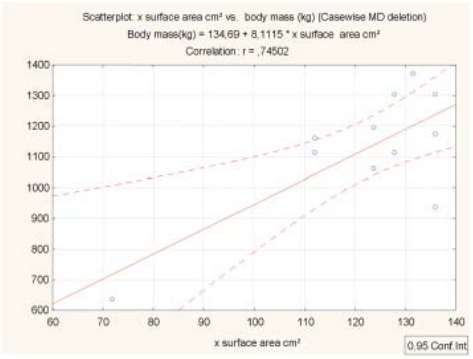


Fig. 4.1. Fig. 4.2.

Fig. 4. Diagrams depicting the correlation between heel height and body mass in front (Fig. 4.1.) and hind (Fig. 4.2.) limbs



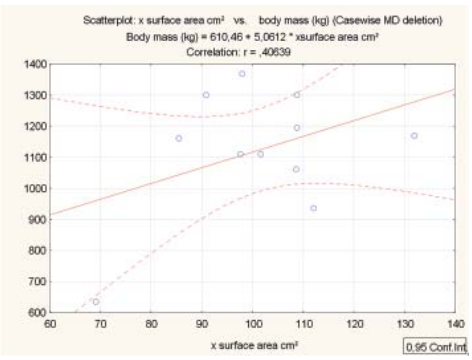


Fig. 5.1. Fig. 5.2.

Fig. 5. Diagrams depicting the correlation between the surface area of the hoof and body mass in front (Fig. 5.1.) and hind (Fig. 5.2.) limbs

Table 4. Correlation between total surface area of the hooves and body mass

Correlation	Number of animals P<0.05; N = 11
Variables	Body mass (kg)
Total surface area of the hooves	0.57

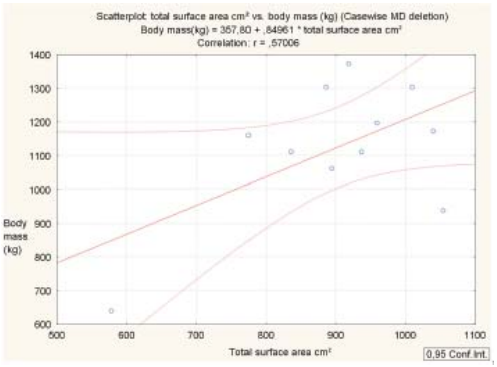


Fig. 6. Diagram depicting the correlation between the total surface area of the hooves of all 11 bulls and their body mass

Discussion

Finisher bulls are liable to pathological alterations of their forelimb hooves when they are not trimmed on a regular basis (SIGMUND et al., 2010). Differences between measurements of lateral and medial hind limb hooves in finisher bulls have also been published (PAULUS and NUSS, 2006). As is well-known, common hoof diseases in bovines cause different degrees of lameness, which results in significant production losses (SPRECHER et al., 1997; WARNICK et al., 2001; ANDERSON and DESROCHERS, 2004; DOHERTY, 2005; KOS et al., 2006; RADOSTITS et al., 2007). Despite the fact that the centre of body mass is located more towards the forelimbs of cattle, sole ulcers and other hoof horn disruptions occur far more frequently in the hind limbs (SIGMUND et al., 2010). Because of the greater weight-bearing on it (compared with the medial hind hoof), the lateral hoof appears to have a predisposition to disease in cattle kept on hard surfaces (NUSS et al., 2011). In the hind limbs, asymmetry of paired hooves has been documented (NUSS and PAULUS, 2006) and this difference in hoof size is related to the greater weight-bearing by the lateral hoof (VAN DER TOL et al., 2002). The medial hooves of the forelimbs bear more weight than the lateral hooves (TOUSSAINT RAVEN, 1989; VAN DER TOL et al., 2002), thus the lateral hooves are more commonly affected by sole ulcers (MURRAY et al., 1996). The trimming of healthy and pathologically altered hooves meets certain criteria which can be set as a rule arising from consecutive and systematized measurement of the hoof (TOUSSAINT RAVEN, 1985; WEAVER, 1985; GREENOUGH et al., 1997). The statistical analysis of the data provided an insight into the correlation between the measured values and the bulls' body mass at a certain level. The standard measurements of a normal and healthy hoof have been well established in cows (FESSL, 1968; GREENOUGH et al., 1997; KEHLER and SOHRT, 2000; NUSS and PAULUS, 2006) and on the basis of these measurements trimming is carried out (TOUSSAINT RAVEN, 1985; WEAVER, 1985; GREENOUGH et al., 1997; STANEK, 1997). Sole thickness contributes significantly to hoof integrity and constitutes a critical parameter for foot trimming in cattle as a number of other measures depend on it (FESSL, 1968; NUSS and PAULUS, 2006). The sole thickness cannot be determined because we took measurements from live bulls. The hoof length is the distance measured from the tip of the hoof to the dorsal part of the crown edge (mean length: 7.5 centimetres) in cows. The dorsal wall angle that the hoof length forms with the ground is 40 - 45 degrees in front and 50 degrees in the hind limbs in cows. The dorsal wall angle that the hoof length forms with the ground is 59 degrees in the front and 57 degrees in the hind limb in finisher bulls. The dorsal wall angle was not measured in this study. The heel height is the distance measured from the junction of the skin and the horn at the back part of the hoof and the ground (mean length: 3.75 centimetres) in cows. The width of the sole is the widest point on the solear surface (mean length: 4 centimetres) in cows (GREENOUGH et al., 1997). The length of the hoof in the front legs is the parameter which showed statistically significant aberrations between the

compared measurements in all bulls. The median value of hoof length in the front limbs compared to that of the hind limbs was slightly lower in all bulls. The correlation degree between hoof length and body mass in the front limbs was fourfold higher than in the hind limbs. This is accounted for by the fact that the front legs bear more weight and when body mass increases, their length increases as well. The aberrations between the obtained measurements of hoof length in the front limbs and the predicted results can be accounted for by the fact that trimming the front limb hooves was rendered difficult by the live animals' restlessness and their leaning on one front limb, which is overburdened by the front part of the body during trimming. The higher degree of correlation between the front limb hooves than the hind limb hooves could be due to the fact that the shape of the front limb hooves is much more regular. It could also be due to the fact that the front limb hooves do not undergo as many changes as the hind limb hooves. The median value of the hoof height was almost the same in both the front and hind limb hooves. The degree of correlation between hoof height and body mass is negligible in the hind limb hooves, whereas there is no correlation in the front limb hooves. It is clear that changes in body mass do not significantly affect the height of the hoof. There is no statistically significant difference between the compared values in the front and hind limb hooves. The measurements of heel height in front and hind limb hooves do not indicate significant alterations according to any of the parameters. It is interesting to note that the median value of the heel height in the front limb hooves was slightly higher than the median value of the heel height in the hind limb hooves. This could be accounted for by the fact that the trimming of the hind leg hooves was easier and more precise, whereas the hoof horn in the front limb hooves was much firmer, which resulted in imprecise trimming. The heel in the front limbs is higher than in the hind limbs regardless of trimming (SIGMUND et al., 2010). The negative correlation between the heel height in the front and especially hind limb hooves and body mass indicates that the increased body mass overburdens the legs, and therefore their heel part as well. The average surface area of the front limb hooves was 20 percent larger than the average surface area of the hind limb hooves. There are no statistically relevant differences between the obtained measurements within the group according to this parameter. A degree of correlation existed for the total surface area of hooves in relation to the body mass of service bulls, and this correlation was more pronounced in the hoof surface of the front limb hooves and body weight than the surface of the hind limb hooves and body weight. Hoof area increases with increasing body weight and the degree of correlation was more pronounced in the front limb hooves than the hind limb hooves. This is accounted for by the fact that front limb hooves are under more physiological strain. The correlation of total surface area of all hooves and body mass was also high.

Conclusions

A negative correlation between the obtained measurements of the heel height in the front and hind limb hooves and body mass indicates that the increase in body mass overburdens the legs, and therefore their heel parts. The average surface area of the front leg hooves was 20 percent larger compared to the surface area of hind limb hooves. There was a high degree of correlation between the surface area of the hoof and the increase in body mass, and the correlation was twice the level in the front limbs, compared with the hind limbs. This is accounted for by the fact that the front limbs are under more physiological strain. The correlation of the total surface area of all hooves and body mass was also high.

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SAŽETAK

Cilj rada bio je odrediti standardne mjere dužine nokta (papka), visine papka, visine pete papka te površine papka u rasplodnih bikova kao pokazatelje prilikom korekcije papaka. U radu su obrađeni zdravi i patološki promijenjeni papci 11 bikova simentalske pasmine u vlasništvu Centra za reprodukciju u stočarstvu Hrvatske, Križevci. Nakon izmjere navedenih dimenzija izračunate su njihove srednje vrijednosti, utvrđena je statistička značajnost razlika vrijednosti unutar skupine svakog pojedinog pokazatelja te je određena korelacija srednje vrijednosti određenog pokazatelja i tjelesne mase svakoga pojedinog bika. Prosječna dužina nokta prednjih nogu istraživane pasmine rasplodnih bikova bila je 9,39 cm, a prosječna dužina nokta stražnjih nogu 9,92 cm. Prosječna visina papka prednjih nogu rasplodnih bikova iznosila je 8,65 cm, a prosječna visina papka stražnjih nogu 8,63 cm. Prosječna visina pete prednjih nogu rasplodnih bikova iznosila je 5,93 cm, a prosječna visina papka stražnjih nogu 5,09 cm. Prosječna vrijednost površine papka na prednjim nogama bila je 122,46 cm^2, a na stražnjim 102,49 cm^2. Stupanj korelacije između dužine papka i tjelesne mase prednjih nogu četiri je puta veći nego na stražnjim nogama. Korekcija papaka prednjih nogu živih bikova bila je otežana zbog nemira životinje i preopterećenja kontralateralne noge tijekom korekcije, a uz to je rožina papaka prednjih nogu bila puno čvršća, negoli stražnjih nogu što je imalo utjecaj na preciznost izmjere papaka. Negativan stupanj korelacije između visine pete papaka prednjih i stražnjih nogu i tjelesne mase upućuje na zaključak da se povećanjem tjelesne mase više opterećuju petni dijelovi papaka. Prosječna površina papaka prednjih nogu je 20% veća od prosječne površine papaka stražnjih nogu. Značajna i vrlo visoka povezanost postoji za ukupnu površinu papaka u odnosu na tjelesnu masu rasplodnih bikova, a ta korelacija je naglašenija u usporedbi površine papaka prednjih nogu i tjelesne mase negoli površine papaka stražnjih nogu i tjelesne mase. Površina papka raste s porastom tjelesne mase, a stupanj povezanosti je izraženiji na prednjim nogama, negoli na stražnjim. To je povezano s činjenicom da prednje noge, vrlo vjerojatno, trpe veće fiziološko opterećenje. Stupanj korelacije ukupne površine papaka svih udova i tjelesne mase također je visok.

Ključne riječi: rasplodni bikovi, izmjere papaka, tjelesna masa