

## MORPHOLOGICAL MEASUREMENTS AND THEIR HERITABILITIES FOR SAHIWAL CATTLE IN PAKISTAN

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### ABSTRACT

Morphological measurements are the characteristics needed to describe morphology of animals. The present study was conducted on Sahiwal cattle of Pakistan to investigate body dimensions and to find their genetic control. The body measurements were recorded on 310 Sahiwal cows kept at three livestock farms. The freshly calved lactating cows from parity first to five were included. Measurements were recorded three times; at early, mid and end of lactation period. Pedigree file was generated from available records in order to estimate heritabilities. Animal model using REML procedure was employed for estimating variance components and heritabilities through ASREML software. Most of the body measurements presented medium to high genetic control on them. Heritability estimates ranged from 0.52±0.04 (neck length) to 0.95±0.01 (naval length and tail length). The heritability estimates were more than 0.70 for body length, diagonal body length, ear width, dewlap width, rump width (Hook to hook), rump width (Pin to pin), rump length (Hook to pin), height at wither, height at sixth rib, height at last rib, height at spine, height at hook bone and height at pin bone. This amount of genetic control revealed that selection for some of body measurements could be effective and the body frame of Sahiwal cattle can be molded according to desire through genetic selection.

**Key words:** Sahiwal cattle, morphological measurements, heritability, genetic control, animal model.

### INTRODUCTION

Sahiwal is an important Zebu cattle breed of particular interest for tropical environments. Animals of this breed are known for their ability of heat tolerance, disease resistance and adaptability to low input systems. The cattle breed has been used for development of dairy and beef synthetics and for up gradation of cattle populations in many countries. Indiscriminate crossbreeding and poorly designed breeding programs are the major reasons for deterioration of this local genetic resource (Bhatti *et al.*, 2007; Rehman *et al.*, 2008). Presently, world wide efforts are being made to identify, evaluate and conserve various animal genetic resources (FAO, 2007). In this context, phenotypic characterization has become very important in the breed standards development. Generally speaking, descriptive breed characteristics mainly pertain to measurements of body frame, back and legs (Trimberger *et al.*, 1987).

Physical characterization and body measurements have been reported for Krishna valley cattle in India (Karthickeyan *et al.*, 2006), North Bengal Grey cattle of Bangladesh (Al-Amin *et al.*, 2007), Deshi cattle of West Bengal (Sarkar *et al.*, 2007), crossbred strains of cattle (Mitra *et al.*, 1993) and Holsteins (Vinson *et al.*, 1982), and local cows of Manipur, India (Tolenkhomba *et al.*, 2012). The phenotypic characterization of Gojri buffalo from India has been

made to explain the body conformation of the said buffalo and support the breeding programs (Vohra *et al.*, 2015). The body measurement traits are reported to be heritable. The knowledge regarding heritability of the traits is a prerequisite for designing any breeding program. Multi-trait heritability estimates of body measurements and their correlations with milk production traits for Holsteins have been reported (Lin *et al.*, 1987). The body measurements and their heritability estimates are very important for designing any breeding program. The genetic correlations among the traits are indicative of pleiotropic effects. The traits with strong genetics correlations could be grouped together to include in any selection index.

Several previous studies have reported productive and reproductive records of Sahiwal cattle (Iqbal, 1996; Dahlin, 1998; Javed, 1999 and Rehman, 2004). The main focus by Dahlin has been on the population structure of breed, genetic and environmental causes of variation in milk production, body weight and reproduction traits. Iqbal (1996) utilized partial records for prediction of complete lactation yield and made comparison of different methods for prediction of milk yield. Javed (1999) mainly concentrated on the genetic and phenotypic aspect of some of the performance traits. These studies have utilized major data sets available and have made recommendations and future strategies for selection and breeding of Sahiwal cattle in Pakistan. An earlier by Hasnain and Shah (1985) provides good

information regarding the production, growth traits and reproductive traits but there is lack of information regarding morphometric characteristics and their heritability estimates. The present study was designed to get morphological measurements and their heritability estimates for Sahiwal cows of Pakistan.

## MATERIALS AND METHODS

The freshly calved cows from three institutional herds located in Punjab Pakistan namely Livestock Experiment Station Bahadurnagar District Okara, Livestock Experiment Station Jahangirabad District Khanewal and Livestock Experiment Station Khizerabad District Sargodha were selected. The morphological

measurements on 310 Sahiwal cows from parity first to fifth were recorded in standing position with squarely placed four legs and neck raised at normal position. The measurements were recorded with L shaped metallic measuring scale, locally manufactured calipers and measuring tape in centimeters. The measurements were recorded three times during the lactation period provided animal remained in milk. Hence number of measurements on each animal varies from one to three making total 790 observations on 310 cows. The body measurements were recorded as per (Shanks and Spahr 1982; Vinson *et al.*, 1982; Ali *et al.*, 1984 and Lucas *et al.*, 1984). The description of body measurements and their abbreviations are presented in Table 1.

**Table 1. Descriptions and abbreviations for different body measurements (cm) of Sahiwal cows**

Trait	Description
Body length (BL)	Horizontal distance from withers to pin bone
Diagonal body length (DBL)	Distance from point of shoulder to pin bone
Neck length (NL)	Flapping distance from Anterior point of hump to poll
Ear length (EL)	Base to tip
Ear width (EW)	Width at the maximum
Height at withers (HW)	Vertical distance from withers to ground
Height at 6 <sup>th</sup> rib (H6thR)	Vertical distance from sixth rib to the ground
Height at last rib (HLR)	Vertical distance from middle of body to the ground
Height at sacrum (HS)	Vertical distance from sacrum (in between hook bones) to the ground
Height at hook (HHB)bone	Vertical distance from hook bone to the ground
Height at pin bone (HPB)	Vertical distance from pin bone to the ground
Rump width (RW)	Hook to hook distance at top most points of the rump
Rump width (RW)	Pin to pin distance at posterior position
Rump length (RL)	Hook to pin distance at top most points
Thurl Width (TW)	Distance between hip bones measured with caliper
Naval length (NVL)	Length from nearest body to end of naval
Dewlap width (DW)	Width of skin folds at maximum
Heel depth (HD)	From hair line to ground
Tail length (TL)	Distance from base of tail to tip leaving hairs

**Statistical analysis:** The statistical model for revealing the effect of various sources of variation on any measured trait included herd and parity. The cows were placed into two parity groups (first parity and later parities). The linear and quadratic effect of age at measurement was fitted as co-variable. Animal was fitted as random. The variances and co-variances were estimated through residual or restricted maximum likelihood (REML) procedures developed by Patterson and Thompson (1971). Univariate animal model was fitted for estimation of the heritability of the traits in the following form. The genetic and phenotypic correlations were estimated in bivariate analyses. For estimation of genetic and phenotypic correlations between body measurements and milk yield, measurements recorded at first stage of lactation were utilized and stage of lactation was

excluded from the model. Following was the model whose different combinations were used for various traits

$$Y_{ijkl} = \mu + H_i + P_j + b_1(a_{ijk}) + b_2(a_{ijk})^2 + A_k + e_{ijkl}$$

**Where**

$Y_{ijkl}$  = a measurement trait of an animal

$\mu$  = overall mean

$H_i$  = effect of  $i^{\text{th}}$  herd (1-3)

$P_j$  = effect of  $j^{\text{th}}$  parity (1-2)

$A_k$  = random animal effect with mean zero and variance  $\sigma^2A$

$a_{ijk}$  = age at classification with  $b_1$  and  $b_2$  being the linear and quadratic regression coefficients of traits on age at measurement

$e_{ijkl}$  = random error with  $l^{\text{th}}$  measurement on  $k^{\text{th}}$  animal in  $j^{\text{th}}$  parity and present in  $i^{\text{th}}$  herd

The analysis was performed using ASREML version 2.0 computer software (Gilmour *et al.*, 2007). Factors analysis was applied to 22 variables including body measurements and milk yield traits. Extraction was made with maximum likelihood method and was based on eigenvalues  $>1$ . The rotation method used was varimax with Kaiser normalization which assumes that factors were not correlated. The rotation was converged in six iterations. The small coefficients below 0.30 were suppressed in order to draw meaningful factors.

## RESULTS

The descriptive statistics for body measurements are given in Table 2. The coefficient of variation ranged from 3.2% for height at hook bone to 24.3% for naval length. The variation for bone structure associated measurements was small. There was a wide variation observed in naval length and dewlap width. The measurements ranged from (4-21 cm) for naval length and 8-26 cm for dewlap width. The differences might be because of management differences. It has been observed that well milk fed calves have a longer naval length and dewlap width. The calves were used for milk let down at khizerabad and were fed small amount of milk through suckling directly from their dams. The calves were nipple fed at Jahangirabad and Bahadurnagar. So the human source of variation could affect feeding that ultimately affected navel and dewlap development. The means for Rump length (Hook to pin) and Rump width (Hook to hook distance) were almost of equal in magnitude indicated that rump length and rump width in Sahiwal were almost of equal size. That gives a rounded shape to the rump area in Sahiwal cows. The height of the Sahiwal cows at spine region is higher than at withers. Although, apparently it looks that Sahiwal cows are higher at wither (hump).

The herd was a significant source of variation for body length, diagonal body length, ear length, ear width, dewlap width, rump width (Hook to hook), rump length (Hook to pin), height at withers, height at sixth rib, height at last rib, height at spine, height at pin bone, heel depth, and tail length ( $P \leq 0.001$ ). Herd differences were also significant for rump width (Pin to pin) and height at hook bone ( $P \leq 0.01$ ); however, the herd differences for neck length and naval length were not significant ( $P \leq 0.05$ ).

The parity factor significantly affected neck length, body length, tail length, diagonal body length, ear length, rump width (Hook to hook), rump length (Hook to pin), height at withers, height at sixth rib, height at last rib, height at spine, height at hook bone and height at pin

bone ( $P \leq 0.001$ ). Parity of cows was also a significant source of variation for ear width ( $P \leq 0.05$ ). Naval length, dewlap width and rump width (Pin to pin) were not affected by parity of cow. The linear and quadratic regression coefficients for age of cows at body measurements are presented in Table 5. Diagonal body length, rump width (Pin to pin) and rump length (hook to pin) were affected by age of the cow at measurement ( $P \leq 0.05$ ). The quadratic effect of age at measurement was significant for rump width (Hook to hook) ( $P \leq 0.05$ ).

**Genetic parameters:** The heritability estimates and standard errors for body measurements are presented in Table 6. The heritability estimates fall in medium to high range. The estimates ranged from  $0.52 \pm 0.04$  for neck length to  $0.95 \pm 0.01$  for naval length and tail length. The other traits with estimates more than 0.70 were for body length, diagonal body length, ear width, dewlap width, rump width (Hook to hook), rump width (Pin to pin), rump length (Hook to pin), height at wither, height at sixth rib, height at last rib, height at spine, height at hook bone and height at pin bone.

The phenotypic and genetic correlations between body measurements and milk yield traits are presented in Table 7. The most of phenotypic and genetic correlations were in lower range and less than 0.10. The highest phenotypic correlation ( $0.48 \pm 0.06$ ) was of rump length (Hook to Pin) with 305-day milk yield. Among others, height at spine was the only trait having a phenotypic correlation of magnitude 0.20 with measurement-day milk yield. Height at withers, height at spine and height at pin bone, had a genetic correlation of magnitude greater than or equal to 0.20 with measurement-day milk yield. The height at spine had a genetic correlation of magnitude more than or equal to 0.20 with 305-day milk yield.

**Factors Analysis:** The five common latent factors ( $F_1$  to  $F_5$  with Eigen values  $>1$ ) which explained 60.248 of the total variance were extracted (Table 8). The communality values indicated that the common factors explained 0.907, 0.851, 0.746, 0.655 and 0.542 proportion of total variance in variables like height at withers, height at sixth rib, height at hook bone, height at pin bone and hook to hook distance (Rump width) (Table 9). The factor 1 included height associated variables like height at hook bone, height at withers, height at 6<sup>th</sup> rib, height at pin bone and height at last rib. The factor 2 had highest association with body length and diagonal body length. The factor 3 showed association with milk yield traits. The factor 4 showed association with ear length and ear width and factor 5 explained just neck length (Table 9).

**Table 2. The means, minimum, maximum (cm) and coefficient of variation (CV %) for body traits**

Trait	Number of observations	Minimum	Maximum	Mean±SD	CV (%)
Neck Length	790	25	56	37.4±4.90	13.1
Body length	790	106	143	124.0±5.83	4.7
Diagonal body length	790	109	148	130.3±6.46	4.9
Ear length	790	20	32	25.6±1.70	6.6
Ear width	790	13	19	15.8±0.89	5.6
Naval length	790	4	21	11.8±2.87	24.3
Dewlap Width	790	8	26	15.4±2.51	16.3
Rump width (Hook to hook)	790	27	43	33.7±2.37	7.0
Rump width (Pin to pin)	790	12	20	15.9±1.43	8.9
Rump length (Hook to pin)	790	28	42	34.3±1.88	5.5
Height at wither	790	109	136	123.6±4.50	3.6
Height at sixth rib	790	105	130	118.8±3.94	3.3
Height at last rib	790	105	131	119.1±3.83	3.2
Height at spine	790	112	139	124.7±4.13	3.3
Height at hook bone	790	109	140	122.4±3.93	3.2
Height at pin bone	790	103	139	115.4±3.83	3.3
Heel depth	790	1	4	2.6±0.54	20.8
Tail length	790	61	135	99.8±7.49	7.5

**Table 3. Means and standard deviations for body measurements (cm) at three herds**

Trait	Level of significance	Farms		
		Bahadurnagar	Jahangirabad	Khizerabad
Neck Length	NS	38.1±6.67	36.7±5.23	37.9±4.32
Body length	***	122.7±5.97a	125.8±5.71ab	124.1±5.29a
Diagonal body length	***	128.4±6.47a	131.3±6.86bc	132.1±5.35c
Ear length	***	25.2±1.83a	25.4±1.57a	26.3±1.35b
Ear width	***	15.5±0.98a	15.9±0.86a	15.8±0.69ab
Naval length	NS	11.9±2.71	11.6±3.13	11.9±2.87
Dewlap Width	***	15.9±0.20c	15.7±0.25b	14.4±0.25a
Rump width (Hook to hook)	***	32.9±2.02a	35.1±2.56b	33.4±2.12a
Rump width (Pin to pin)	**	15.6±1.38a	15.9±1.46ab	16.2±1.38b
Rump length (Hook to pin)	***	33.8±1.78a	35.0±2.02ab	34.4±1.69a
Height at wither	***	122.4±4.32a	126.3±4.40b	122.8±3.85a
Height at sixth rib	***	117.7±3.67a	120.1±3.91ab	119.1±3.94a
Height at last rib	***	118.3±3.61a	120.3±3.99b	119.1±3.71a
Height at spine	***	124.1±3.86b	126.9±4.35ab	123.7±3.60a
Height at hook bone	**	121.9±3.89a	123.8±4.22b	121.8±3.41a
Height at pin bone	***	115.2±3.74a	117.2±3.71b	114.2±3.48a
Heel depth	***	2.5±0.52a	2.6±.62a	2.8±.46ab
Tail length	***	98.9±7.11a	98.7±8.10ab	101.9±6.98b

†\* = significant at  $P \leq 0.05$ , \*\* = significant at  $P \leq 0.01$ , \*\*\* = significant at  $P \leq 0.001$ , NS = non-significant.

**Table 4. Means and standard deviations for body measurements (cm) in different parities**

Trait	Level of significance	Parity	
		First	Second and Later
Neck Length	***	35.9±5.32	38.5±5.64
Body length	***	120.1±5.60	125.9±4.90
Diagonal body length	***	125.4±5.42	132.7±5.51
Ear length	***	25.1±1.83	25.8±1.67
Ear width	*	15.6±0.85	15.8±0.90

Naval length	NS	11.6±2.97	11.9±2.82
Dewlap Width	NS	15.3±2.68	15.5±2.42
Rump width (Hook to hook)	***	32.6±2.25	34.2±2.26
Rump width (Pin to pin)	NS	15.7±1.26	16.0±1.49
Rump length (Hook to pin)	***	33.5±1.71	34.7±1.82
Height at wither	***	121.7±4.17	124.5±4.37
Height at sixth rib	***	117.0±3.94	119.6±3.65
Height at last rib	***	117.7±3.86	119.7±3.65
Height at spine	***	123.7±4.15	125.2±4.03
Height at hook bone	***	121.3±3.86	122.9±3.86
Height at pin bone	***	114.5±3.62	115.9±3.85
Heel depth	NS	2.6±0.53	2.7±0.55
Tail length	***	97.3±5.94	101.0±7.86

†\* = significant at  $P \leq 0.05$ , \*\* = significant at  $P \leq 0.01$ , \*\*\* = significant at  $P \leq 0.001$ , NS = non-significant.

**Table 5. Linear ( $b_1$ ) and quadratic ( $b_2$ ) regression coefficients for age of cow at measurement†**

Trait	$\alpha$	Regression estimates			
		$b_1$	Level of Significance	$b_2$	Level of Significance
Neck Length	33.53	0.1428	NS	-0.0008	NS
Body length	116.4	0.0670	NS	-0.0003	NS
Diagonal body length	124.0	-0.0165	*	0.0003	NS
Ear length	23.96	0.0237	NS	-0.0001	NS
Ear width	15.41	-0.0036	NS	0.0000	NS
Naval length	12.11	-0.0131	NS	0.0001	NS
Dewlap Width	15.09	0.0141	NS	-0.0001	NS
Rump width (Hook to hook)	29.46	0.0661	NS	-0.0004	*
Rump width (Pin to pin)	15.85	0.0178	*	0.0001	NS
Rump length (Hook to pin)	33.07	-0.0030	*	0.0000	NS
Height at wither	117.5	0.0696	NS	-0.0004	NS
Height at sixth rib	114.9	0.0308	NS	-0.0001	NS
Height at last rib	115.7	0.0431	NS	-0.0002	NS
Height at spine	122.3	0.0271	NS	-0.0001	NS
Height at hook bone	118.9	0.0603	NS	-0.0004	NS
Height at pin bone	112.4	0.0569	NS	-0.0003	NS
Heel depth	2.480	0.0008	NS	-0.0000	NS
Tail length	96.32	-0.0102	NS	0.0002	NS

†\* = significant at  $P \leq 0.05$ , \*\* = significant at  $P \leq 0.01$ , \*\*\* = significant at  $P \leq 0.001$ , NS = non-significant.

**Table 6. Heritability estimates and standard errors of body measurement traits**

Traits	$h^2 \pm SE$	Traits	$h^2 \pm SE$
Neck length	0.52±0.04	Rump length (Hook to pin)	0.76±0.02
Body length	0.81±0.02	Height at Wither	0.86±0.01
Diagonal body length	0.73±0.02	Height at 6 <sup>th</sup> Rib	0.84±0.02
Ear length	0.68±0.03	Height at Last Rib	0.83±0.02
Ear width	0.75±0.02	Height at Spine	0.83±0.02
Naval length	0.95±0.01	Height at Hook Bone	0.79±0.02
Dewlap width	0.75±0.02	Height at Pin Bone	0.74±0.02
Rump Width (Hook to hook)	0.80±0.02	Heel Depth	0.62±0.03
Rump width (Pin to pin)	0.80±0.02	Tail length	0.95±0.01

**Table 7 Genetic and phenotypic correlations between body measurements and milk yield**

Trait	Phenotypic correlations		Genetic correlations	
	Measurement day-yield	305-day yield	Measurement day-yield	305-day yield
NL	-0.10±0.06	-0.11±0.06	0.01±0.00	-0.00 ±0.00
BL	0.02±0.06	0.09±0.06	0.19±0.00	0.17±0.00
TL	0.01±0.06	0.12±0.06	0.05±0.00	0.10±0.00
DBL	0.05±0.06	0.10±0.06	0.17±0.00	0.13±0.00
EL	-0.08±0.06	0.07±0.06	0.02±0.00	0.04±0.00
EW	-0.09±0.06	0.04±0.06	0.04±0.00	0.05±0.00
NVL	0.07±0.06	-0.05±0.06	0.10±0.00	0.08±0.00
DW	-0.03±0.06	-0.05±0.06	0.09±0.00	0.09±0.00
RWHH	-0.01±0.06	0.05±0.06	0.02±0.00	0.14±0.00
RWPP	-0.13±0.06	0.12±0.06	-0.01±0.00	0.17±0.00
RLHP	0.07±0.06	0.48±0.06	0.20±0.00	0.10±0.00
HW	0.11±0.06	0.09±0.06	0.22±0.00	0.17±0.00
H6R	0.06±0.06	0.06±0.06	0.15±0.00	0.12±0.00
HLR	0.06±0.06	0.17±0.06	0.13±0.00	0.10±0.00
HS	0.20±0.05	0.17±0.06	0.24±0.00	0.20±0.00
HHB	0.15±0.06	0.15±0.06	0.18±0.00	0.16±0.00
HPB	0.13±0.06	0.09±0.06	0.20±0.00	0.16±0.00
HD	0.02±0.06	0.04±0.06	0.01±0.00	0.00±0.00

**Table 8. Total variance explained by different factors with maximum likelihood method**

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.602	33.012	33.012	6.140	30.700	30.700	3.477	17.387	17.387
2	1.703	8.515	41.528	1.361	6.803	37.504	2.683	13.416	30.803
3	1.345	6.726	48.254	.789	3.943	41.447	1.576	7.881	38.684
4	1.227	6.133	54.387	.741	3.706	45.153	1.160	5.800	44.484
5	1.172	5.861	60.248	.602	3.008	48.161	.735	3.677	48.161

**Table 9. Communalities (the proportion of variance of each item that is explained by the factors obtained with maximum likelihood method)**

Variables	Initial	Extraction	Variables	Initial	Extraction
BL	.619	.727	HTP	.529	.555
DBL	.535	.593	RW	.259	.240
NL	.309	.465	TL	.195	.157
HW	.824	.907	EL	.271	.545
HS	.213	.209	EW	.281	.400
HHB	.700	.746	NVL	.174	.065
HPB	.618	.655	DW	.158	.070
H6THR	.821	.851	HD	.065	.034
HLR	.367	.365	AV-3 Day milk yield	.580	.725
HTH	.550	.542	305-day milk yield	.586	.781

Table 10. Rotated factor matrix with coefficients equal to 0.30 suppressed

Variables	Factor				
	1	2	3	4	5
HHB	.784				
H6THR	.768	.460			
HW	.753	.507			
HPB	.725				
HLR	.539				
HS	.410				
DW					
NVL					
BL	.327	.716			
DBL		.684			
HTH	.352	.617			
HTP	.391	.577			
RW		.367			
TL					
HD					
305-day yield			.857		
Measurement Day yield			.826		
EL				.693	
EW				.566	
Necklength					.640

## DISCUSSION

The body measurements may vary because of breed differences. The Sahiwal cattle belong to Zebu. The comparison of body measurements among the Zebu breeds could make some sense. However comparison of Sahiwal cattle with temperate cattle is not very much justified. But because most of the literature is available on temperate cattle, so references from temperate cattle are included in discussion. The mean height at withers for USA Holstein 138.6 cm (Vinson *et al.*, 1982), 139.1±4.23 for Canadian Holstein (Ali *et al.*, 1984) and 129.0±4.1 (Lin *et al.*, 1987) were higher than current study mean (123.6 cm). An average of the cow's height at withers 94-121 cm (Bonczek *et al.*, 1992; Karthickeyan *et al.*, 2006; Al-Amin *et al.*, 2007; Sarkar *et al.*, 2007; Tolankhomba *et al.*, 2012; Verma *et al.*, 2015) was lower compared with the present study. The mean height at withers was comparable 123.5 cm (Bayram *et al.*, 2006) and higher than Sahiwal in the present study for Holsteins 134.4 cm (Sieber *et al.*, 1988), 138.6 cm (Vinson *et al.*, 1982) and 138.4 cm (Lucas *et al.*, 1984). The breed differences could be the probable cause for this variation. The significant herd differences found for height and length traits indicated management differences. Significant parity differences for length and height traits and even for ear length indicated that growth in Sahiwal cows continued even after completion of first parity. Significant age of cow effect (Ali *et al.*, 1984) reported for rump width (Pin to pin) and herd effects for rump width, rump length, height at wither, height at sacrum

between hooks, height at hook bone and height at pin bone were in agreement with the present study. Higher than present study the, height at sacrum 137 cm has been reported for Holstein cows (Shanks and Spahr, 1982).

The average body length in present study was higher than the average reported for North Bengal Grey cattle of Bangladesh 105±8.5 cm (Al-Amin *et al.*, 2007) and local cows of Manipur India 111.34±0.92 (Tolankhomba *et al.*, 2012)., The body length reported for Krishna Valley cattle 128.4±2.0 cm (Karthickeyan *et al.*, 2006), 167.6 cm for Deshi cattle of West Bengal (Sarkar *et al.*, 2007) and 131.4 cm for Holsteins (Bonczek *et al.*, 1992) were higher than present study mean. The Krishna valley cattle and Deshi cattle of West Bengal fall under Zebu category and could be compared with Sahiwal. The mean estimates for these two breeds indicated that cows from these breeds were longer than Sahiwal cows of Pakistan. This statement will hold true provided that the trait definition was same. The average diagonal body length 141.0 cm for Holsteins was also higher than that obtained in the current study (Bayram *et al.*, 2006) and 158.3 cm (Sieber *et al.*, 1988). While making comparison of height and length of Sahiwal cows in present study with other breeds particularly Holstein cattle, it looks that Sahiwal cows are short of structure. So there is scope to improve the height and length of Sahiwal cattle through selection with some caution. However the correlations among length and height traits and some other traits of economic importance should be considered. The negative correlation between height and length of cows and feed efficiency traits has been

reported (Seiber *et al.*, 1988). Rump length and rump width was reported higher for Holsteins (Ali *et al.*, 1984; Bayram *et al.*, 2006) in comparison with the Sahiwal cows in current study. However the rump width (hook to hook distance) reported for Hill cattle from state of Himachal Pradesh  $27.22 \pm 0.30$  (Verma *et al.*, 2015) was lower than Sahiwal in current study. The local cattle of Manipur India has short ears  $15.24 \pm 0.13$ , tail  $75.50 \pm 0.55$  and neck length  $29.95 \pm 0.21$  cm (Tolenkhomba *et al.*, 2012) than for Sahiwal cattle in current study. The tail length ( $68.04 \pm 0.55$ ), ear length ( $17.78 \pm 0.08$ ) and rump width pin to pin distance ( $12.43 \pm 0.08$ ) for Hill cattle from Himachal Pradesh (Verma *et al.*, 2015) was lower than Sahiwal. The variation could be attributed to breed differences and rearing systems. Secondly, the Holsteins have been selected on conformation basis since long that could be the reason to modify the rump length and width. Rump area provides room for udder attachment. The long and wide rump provides more space for udder. So still there is scope to improve rump length and width in Sahiwal cattle through selection on conformation basis. Besides breed type, definition of the traits could be the factor for difference in magnitude of the traits. In present study rump width was the difference between dorsal tops of the hook bones. For some other studies, this is the distance between outer most positions at the hook bone.

The maximum coefficient of variation for naval length indicated a wide variation in the trait. The ear length, ear width and tail length in the present study were higher than reported for North Bengal Grey cattle of Bangladesh (Al-Amin *et al.*, 2007). Although the North Black Bengal is Zebu type cattle breed but they have short and less wide ears compared to Sahiwal cattle. Within the Zebu a lot of variation in ear length is observed. The Gir cattle of India possess longer ears than Sahiwal. Keeping in view this variation, the Sahiwal cows could be assigned medium category as concern length of ear.

**Genetic parameters:** The heritability estimates for most of the traits were higher than those reported for other breeds. Smaller data set may be a probable cause. The measurements were recorded by a single person over a stipulated period and cows belonged to experimental stations. That could reduce environmental component of variance. However, higher heritability estimates are indicative of possibility of rapid change in desired direction. The heritability for height at sacrum was higher than reported by Koenen and Groen (1998) for Holsteins (0.54) estimated with animal model. Although heritability was estimated with animal model but the environment for both studies could be different that can affect parameter estimates. The heritability estimates for wither height body length and rump length (Brum and Ludwick, 1969; Lin *et al.*, 1987) were lower than present study estimates for Holstein cows. In other study (Shanks and Spahr,

1982) reported lower than present study heritability estimates for height at sacrum and rump width for Holstein cows. Both of these studies used sire as random effect. The sire model does not account for the female relationship and hence under estimate heritability (Miszta, 1990); Vanraden *et al.* 1990). But in present study Animal model was used. So this might be one of the reasons for high heritability estimates. In another study lower than present study heritability estimates for rump width, rump length, height at withers, height at sacrum between hooks, height at hook bone, and height at pin bone has been reported (Ali *et al.* 1984). The heritability estimates in high range similar to present study for wither height (0.73) and body length (0.58) have been reported for Holstein (Touchberry (1951). The estimates obtained in the present study could not be taken as final. The estimates could change with huge data set.

The genetic and phenotypic correlations for most of body measurements and milk yield traits were positive but in low range. The genetic correlations of magnitude of 0.20 or more for 305-day milk yield with height at sacrum were expected to have a correlated response in 305-day milk yield if selecting for these traits. Still it is desired that studies with larger data sets be conducted to make these estimates more reliable.

The phenotypic correlation (0.09) reported for Holstein cows of rump length with 305 day milk yield was lower than current study estimate (Lin *et al.*, 1987). The genetic correlation between wither height and 305-day milk yield (0.35) for Holstein cows was higher than current study estimate (Lin *et al.*, 1987). In another study Bayram *et al.* (2006) reported phenotypic correlation of between rump length and 305-day milk yield 0.22 for Holsteins cows which is lower than current study estimate. The phenotypic correlations of 305-day milk yield with wither height and diagonal body length reported for Holstein cows were in agreement with current study Sieber *et al.* (1988) for Holstein cows.

**Factor analysis:** From the factor analysis it is deduced that height associated traits were more important in explaining of the total variance present in all of the body measurements. From the results it could be decided to implement the factors analysis in the study of morphological measurements in order to simplify the information and devise effective breeding program and reduce the cost of recording measurements. Mazza *et al.* (2016) has performed factor analysis on morphological data of dual-purpose autochthonous breeds.

**Conclusions:** The herd and parity factors were significant sources of variation for most of the body measurement traits in Sahiwal cows. Many of the height associated measurements were not influenced significantly by age of cows at measurement. So it is concluded that Sahiwal cows gained their full structure when they calve for the first time. The heritability

estimates indicated that body measurements are under good genetic control and genetic improvement through selection in a desired direction is possible. The rump length, height at withers and height at spine could be focused for selection of cows under farm and field conditions. The recording of morphological measurements should be started at the farms. That will help in conservation efforts and could be used for selecting future breeding stock. The factors analysis could be performed in evaluation of body measurements to simplify the information received in the form of body measurements.

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