# MORPHOLOGICAL MEASUREMENTS AND THEIR HERITABILITY 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 calves lactating cows from parity first to five were included. Measurements were recorded three times; in 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, body 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 significant in the breed standards. 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), 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 has reported productive and reproductive records of Sahiwal cattle Javed (1999), Rehman (2004), Iqbal (1996) and Dahlin (1998). 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 trait. These studies have utilized major data sets available and have made recommendations and future strategies for selection and breeding of Sahiwal cattle in Pakistan. The study made 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 (DBL) length | 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 $6^{th}$ rib (H6thR) | Vertical distance at sixth rib to the ground |
| Height at last rib (HLR) | Vertical distance at 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

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

**Where**

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

$\mu$ = overall mean

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

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

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

$a_{ijkl}$ = 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 $L^{th}$ measurement on $K^{th}$ animal in $J^{th}$ parity and present in $I^{th}$ 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<0.001). Herd differences were also determined for rump width (Pin to pin) and height at hook bone (P<0.01); however, the herd differences for neck length and naval length were not significant (P<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<0.001). Parity of cows was also a significant source of variation for EW (P<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<0.05). The quadratic effect of age at measurement was significant for rump width (Hook to hook) (P<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±0.04 for neck length to 0.95±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±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. Among others, HW, HS, HPB, had a genetic correlation of magnitude greater than or equal to 0.20 with measurement-day milk yield. The HS 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 0.918, 0.885, 0.739, 0.675 and 0.617 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 $6^{th}$ 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<0.05, ** = significant at P<0.01, *** = significant at P<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 $P<0.05$, $^{**}$ = significant at $P<0.01$, $^{***}$ = significant at $P<0.001$, NS = non-significant.

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

| Trait | α | 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 $P<0.05$, $^{**}$ = significant at $P<0.01$, $^{***}$ = significant at $P<0.001$, NS = non-significant.

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

| Traits | $h^2$±SE | Traits | $h^2$±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$^{th}$ 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 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 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 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; Tolenkhomba 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 (Tolenkhomba 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 high 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 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±0.30 (Verma et al., 2015) was lower than Sahiwal in current study. The local cattle of Manipur India has short ears 15.24±0.13, tail 75.50±0.55 and neck length 29.95±0.21 cm (Tolenkhomba et al., 2012) than for Sahiwal cattle in current study. The tail length (68.04±0.55), ear length (17.78±0.08) and rump width pin to pin distance (12.43±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 (Misztal, 1990); Vanraden *et al.* 1990). But in present study Animal model was used. So this might be one of the reason 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 correlation 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 Sieber *et al.* (1988) for Holstein cows. The genetic correlations of milk yield with body length.

**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 wither and height at spine could be focused for selection of cows under farm and field condition. 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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