## Research Article

# Prediction of Body Weight From Linear Body Measurements in Kashmir Merino Sheep

**Mubashir Ali Rather**[1*], **Imran Bashir**[1], **Ambreen Hamdani**[2], **Nusrat Nabi Khan**[2], **Showkat A. Ahangar**[1], **M. Nazki**

[1]*Department of Sheep Husbandry, Kashmir,* [2]*Division of Animal Genetics and Breeding, SKUAST-Kashmir 190006.*

**Abstract** | Data on 349 Kashmir Merino sheep managed at Government Sheep Breeding Farm Kralpathri, Kashmir for body length (BL), hight at withers (BH), heart girth (HG), paunch girth (PG), tail length (TL), ear length (EL), ear width (EW), face length (FL) and adult body weight (BW) were analysed with the Mixed Model Least Squares and Maximum Likelihood algorithms, PC-2 version computer programme (Harvey. 1990) with sex and year of birth as fixed effects. The effect of year of birth was significant on all traits under study whereas effect of sex was significant on BL, BH, HG, PG, TL and BW. Heritability estimates obtained were high for BH, HG and PG, moderate for BL, EL and TL and low for FL and EB in present study. The genetic and phonetic correlations ranged from to -0.61±0.14 to 0.95±0.34 and -0.12 to 0.74, respectively among different traits. The $R^2$ values for different regression equations developed to predict adult body weight varied from 0.00 to 56.96%. the coefficient multiple determination ($R^2$) values increased with the addition of traits (independent variables or linear body measurements) in the equation and the maximum $R^2$ value of 56.96 % was obtained when all the variables were used together and poor $R^2$ value of 0.00 % was obtained when TL alone was used as the independent variable. The study revealed that the height at withers is the best predictor for the estimation of body weight from body measurements in Kashmir Merino sheep under field conditions. This may be a useful finding in conditions when a weighing balance may not be available with farmer. This also indicates a high correlation between traits and therefore can be used for making selection decisions.

**Keywords** | Kashmir Merino, Measurements, Regression Analysis, Prediction

## INTRODUCTION

Body weights of sheep at different stages of life cycle are very important traits for judging its performance adaptability to existing environmental conditions. The body weight is supplemented with measurements which describes an individual or population more completely than conventional methods of weighing or grading (Ravimurugan et al., 2015). Body measurements of animals are also necessary for establishing breed standards (Riva et al., 2002; Verma et al., 2016). These also provide information about the morphological structure of the animal as well as its physiological status (Ravimurugan et al., 2013), are

helpful in developing suitable selection criteria (Sharaby and Suleiman, 1987) and provide information about developmental ability of the animals (Ravimurugan et al., 2015). The body measurements are also used for estimation of average live body weight of animals (Thiruvenkadan, 2005; Sowande and Sobola, 2008; Tadesse and Gebremariam, 2010; Birteeb et al., 2012; Ravimurugan et al., 2015; Kumar et al., 2018). Body measurement traits and body weights are highly correlated traits. Therefore, the present investigation was carried out to determine the relationship between adult body weight and linear body measurements in Kashmir Merino sheep so as to know the best fitted regression model for prediction its live weight under field

**Table 1**: Least squares means for adult body measurements and body weight in Kashmir Merino sheep

| | N | BW (kg) | BL (Inches) | BH (Inches) | HG (Inches) | PG (Inches) | FL (Inches) | EL (Inches) | EW (Inches) | TL (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| Overall | 413 | 40.98 ±0.44 | 24.47 ±0.18 | 27.37 ±0.18 | 37.03 ±0.28 | 39.61 ±0.32 | 10.10 ±0.08 | 4.10 ±0.08 | 2.73 ±0.05 | 13.74 ±0.25 |
| Age | P. value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.049 | 0.018 |
| 2 year | 11 | 45.12 ±1.31[e] | 24.60 ±0.54[bc] | 28.23 ±0.54[d] | 37.29 ±0.83[d] | 40.36 ±0.96[d] | 10.30 ±0.23[c] | 3.98 ±0.23[ab] | 2.85 ±0.16[b] | 13.66 ±0.74[b] |
| 3 years | 28 | 42.84 ±0.87[cd] | 24.96 ±0.36[c] | 27.45 ±0.36[c] | 37.79 ±0.55[d] | 40.71 ±0.64[d] | 10.09 ±0.15[b] | 3.67 ±0.15[a] | 2.68 ±0.10[a] | 13.62 ±0.49[b] |
| 4 years | 34 | 44.83 ±0.80[d] | 25.06 ±0.33[d] | 28.31 ±0.33[d] | 37.77 ±0.50[de] | 40.89 ±0.59[d] | 10.38 ±0.14[cd] | 4.16 ±0.14[c] | 2.84 ±0.10[ab] | 13.34 ±0.45[a] |
| 5 years | 92 | 44.83 ±0.55[d] | 25.11 ±0.23[d] | 28.12 ±0.23[d] | 38.56 ±0.35[f] | 40.86 ±0.40[d] | 10.21 ±0.10[bc] | 3.98 ±0.10[ab] | 2.77 ±0.07[a] | 13.69 ±0.31[b] |
| 6 years | 84 | 39.86 ±0.57[bc] | 24.37 ±0.24[b] | 27.31 ±0.24[c] | 36.64 ±0.36[bc] | 39.01 ±0.42[cd] | 10.11 ±0.10[b] | 4.13 ±0.10[c] | 2.73 ±0.07[a] | 14.03 ±0.32[c] |
| 7 years | 81 | 37.96 ±0.58[b] | 23.83 ±0.24[a] | 26.90 ±0.24[a] | 36.35 ±0.37[b] | 38.41 ±0.42[b] | 9.92 ±0.10[ab] | 4.17 ±0.10[c] | 2.69 ±0.07[a] | 14.07 ±0.33[cd] |
| 8 years | 83 | 31.45 ±0.51[a] | 23.36 ±0.21[a] | 25.30 ±0.21[a] | 34.80 ±0.32[a] | 37.07 ±0.37[a] | 9.66 ±0.09[a] | 4.63 ±0.09[cd] | 2.54 ±0.06[a] | 13.75 ±0.29[bc] |
| Sex | P value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.336 | 0.450 | 0.000 |
| Female | 381 | 36.32 ±0.27 | 23.55 ±0.11 | 26.37 ±0.11 | 35.74 ±0.17 | 37.89 ±0.20 | 9.85 ±0.05 | 4.17 ±0.05 | 2.69 ±0.03 | 12.94 ±0.15 |
| Male | 32 | 45.65 ±0.79 | 25.39 ±0.33 | 28.37 ±0.33 | 38.32 ±0.50 | 41.34 ±0.58 | 10.35 ±0.14 | 4.04 ±0.14 | 2.77 ±0.09 | 14.53 ±0.44 |

**Table 2:** Genetic parameters for adult body weight and body measurements in Kashmir Merino sheep.

| Trait | BL | BH | HG | PG | FL | EL | EB | TL | BW |
|---|---|---|---|---|---|---|---|---|---|
| BL | 0.37±0.20 | 0.87±0.22 | 0.91±0.24 | 0.85±0.25 | 0.58±0.39 | -0.60±0.40 | 0.51±0.23 | -0.15±0.42 | 0.91±0.19 |
| BH | 0.36 | 0.62±0.22 | 0.91±0.18 | 0.87±0.18 | 0.65±0.35 | -0.49±0.0.30 | 0.51±0.21 | 0.25±0.30 | 0.86±0.07 |
| HG | 0.41 | 0.37 | 0.50±0.21 | 0.83±0.11 | 0.69±0.37 | -0.53±0.35 | 0.56±0.33 | -0.60±0.34 | 0.86±0.07 |
| PG | 0.41 | 0.39 | 0.74 | 0.59±0.61 | 0.58±0.21 | -0.53±0.33 | -0.44±0.58 | -0.0.05±0.35 | 0.89±0.0.10 |
| FL | 0.27 | 0.24 | 0.35 | 0.33 | 0.22±0.20 | -0.45±0.52 | 0.35±0.25 | -0.21±0.53 | 0.95±0.34 |
| EL | 0.03 | -0.12 | 0.02 | -0.004 | -0.03 | 0.42±0.21 | -0.58±0.39 | -0.07±0.41 | -0.61±0.14 |
| EB | 0.49 | 0.29 | 0.14 | 0.18 | 0.18 | 0.34 | 0.23±0.20 | -0.10±0.54 | 0.31±0.34 |
| TL | 0.11 | 0.11 | 0.08 | -0.01 | 0.16 | -0.05 | -0.08 | 0.31±0.20 | -0.02±0.23 |
| BW | 0.48 | 0.60 | 0.54 | 0.54 | 0.36 | 0.15 | 0.30 | 0.02 | 0.50±0.20 |

*Values above the diagonal represent genotypic correlations and the values below the diagonal represent phenotypic correlations*

**Table 3:** Prediction equations and coefficient of determination ($R^2$) of different body measurements

| Eq. No. | Prediction equations | $R^2$ |
|---|---|---|
| 1 | $Y = 35.34 + 0.028\ TL$ | 0.00 |
| 2 | $Y = 40.41 - 1.112\ EL$ | 1.49 |
| 3 | $Y = 25.23 + 3.923\ EB$ | 8.83 |
| 4 | $Y = 6.50 + 2.974\ FL$ | 11.74 |
| 5 | $Y = -4.40 + 1.703\ BL$ | 23.95 |
| 6 | $Y = -5.37 + 1.1496\ HG$ | 28.9 |
| 7 | $Y = -3.14 + 1.0290\ PG$ | 28.82 |

| | | |
|---|---|---|
| 8 | Y = -17.06 + 2.008 BH | 38.50 |
| 9 | Y = -31.28 + 0.7059 HG + 1.589 BH | 46.86 |
| 10 | Y = -33.29 + 0.351 HG + 1.490 BH + 0.4581 PG | 49.44 |
| 11 | Y = -39.59 + 0.277 HG + 1.335 BH + 0.3896 PG + 0.663 BL | 52.09 |
| 12 | Y = -43.89 + 0.249 HG + 1.297 BH + 0.3705 PG + 0.622 BL + 0.811 FL | 52.74 |
| 13 | Y = -44.45 + 0.282 HG + 1.213 BH + 0.3473 PG + 0.587 BL + 0.754 FL + 1.440 EB | 53.74 |
| 14 | Y = -37.28 + 0.322 HG + 1.057 BH + 0.3318 PG + 0.611 BL + 0.679 FL + 2.699 EB - 1.682 EL | 56.74 |
| 15 | Y = -36.20 + 0.325 HG + 1.076 BH + 0.3295 PG + 0.616 BL + 0.734 FL + 2.595 EB - 1.657 EL - 0.1583 TL | 56.96 |

conditions when weighing balance may not be available. Many authors have studied various sheep breeds under field conditions and their performance (Hamadani et al., 2019; Rather et al., 2019; Khan et al., 2020; Hamadani et al., 2020) This may also be important for making selection decisions.

## MATERIALS AND METHODS

The data used in the present study includes biometric traits were observed on 413 adult Kashmir Merino sheep maintained at Sheep Breeding Farm Kralapathri. A flexible measuring tape was used to measure different morphometric viz. body length (BL: distance from point of shoulder to the point of tuber ischii), heart girth (HG: body circumference around the heart just behind the elbow joint), paunch girth (PG: body circumference around the paunch), height at weathers (BH: distance from the base of hoof to the highest point of withers), ear length (EL: length of ear from base of ear), ear width (EW: width of ear at the middle of ear), tail length (TL: length of tail from base of tail) and face length (FL: distance from the beginning of the upper lip to the external occipital protuberance). A hanging digital spring balance was used to measure body weights (BW). Only adult animals above 2 years of age (having completed their growth) were used for the present study. The body measurements were taken on animals in standing position, with head raised, with no body movements and weight on all four feet.

The general linear model of the SPSS software (IBM SPSS Statistics 20) was used for estimation of least squares means and effect of different tangible factors on different traits with sex and year of birth as fixed effects using following mathematical model:

$Y e_{ijk} = P_i + G_j + e_{ijk}$
Where $Y_{ijk}$ is the observation on $k^{th}$ animal having $j^{th}$ sex and born in $i^{th}$ year.

Least-squares and maximum likelihood computer programme of Harvey (1990) was used for estimation of genetic parameters by paternal half sib correlations method using sire component of variance and covariance. The cor-

relation coefficients were used to determine degree of the linear relationship between two continuous variables.

Step wise linear regression analysis was made to identify the best predictor variable for estimating the body weight from body measurements. Regression analysis was performed by including different body measurement individually and collectively as independent variables and body weight as dependent variable in Minitab-17 statistical package. The coefficient multiple determination ($R^2$) was used as criterion to decide the best fitted regression equation.

## RESULTS AND DISCUSSION

### Least Square Means
The overall least square means for BW, BL, BH, HG, HG, FL, EL, EW and TL are presented in Table 1. The effect of year of birth was significant on all traits under study. The effect of year of birth might be due to variation in availability of feed and fodder in different years during stage of body development and growth. Significant effect of year of birth on body measurements was also reported by Tadesse and Gebremariam (2010) in Highland sheep, Petrovic et al. (2012) in Merino landschaf sheep and Jafari, Kumar et al. (2018) in Harnali sheep. The effect of sex was also significant (p<0.01) on all traits except EL and EW. However, sexual dimorphism in favour of male for all traits was observed. Similar findings were also reported by Petrovic et al. (2012) in Merinolandschaf sheep, Jafari and Hashemi (2014) in Makuie sheep, Lalit et al. (2016) in Harnali sheep, Kumar et al. (2018) in Harnali sheep.

### Genetic parameters
The heritability estimates, genetic correlations and phenotypic correlations between different traits are presented in Table 2. The heritability estimates obtained in present study were high for BH, HG and PG, moderate for BL, EL and TL and low for FL and EW. The high heritability estimates indicated the existence of genetic variability which can be harvested through proper selection. Comparative heritability estimates in Beetal goats, West African sheep and Hernali sheep were reported by Waheed et al. (2011), Fadare et al. (2014) and Kumar et al (2018), respectively.

However, lower estimates for BL, BH, HG and PG were reported by Mandal et al. (2010) in Muzaffarnagri sheep, Panda et al. (2014) in Ekda sheep and Bakhshalizadeh et al. (2015) in Moghani. The high heritability estimates of 0.50±0.20 for BW was obtained in the present study was in consonance with findings of Snyman (2012) in Angora goats. However, moderate heritability estimates of 0.38 in Western sheep and 0.42±0.17 in Hernali sheep were reported by Borg et al. (2009) and Kumar et al. (2018), respectively.

### GENETIC AND PHENOTYPIC CORRELATIONS

The phenotypic and genetic correlations between traits under consideration were quite varying in magnitude ranging as is observed from Table 2. The phenotypic correlations of BW with body measurements were positive ranging from 0.02 to 0.60. The genetic correlations between body measurements and body weight were ranging from -0.61±0.14 to 0.86±0.07. Low to high correlations both at genetic and phenotypic level between various body measurements average adult were also reported by Petrovic et al. (2012) in Merinolandschaf sheep, Jafari and Hashemi (2014) in Makuie sheep breed and Kumar et al. (2018) in Harnali sheep. The positive and moderate to high correlations (genetic and phenotypic) of body weight with BL, BH, PG, FL and EB suggested that these body measurements can be used to predict body weight under field conditions where weighing scales may not be available. The positive and moderate to high correlations (genetic and phenotypic) of body weight with BL, BH, PG, FL and EB suggested that body measurements separately or in combinations with each other can be used to predict body weight in Kashmir Merino sheep when weighing scales may not be available.

### PREDICTION OF BODY WEIGHT FROM LINEAR BODY MEASUREMENTS

The step wise regression equations generated from regression analysis of body measurements as independent variables and body weight as dependent variable are presented in Table 3. The coefficient of determination ($R^2$) indicated that the body measurements in combinations were successful to describe more variation in adult live weight in Kashmir Merino. When traits were considered separately the highest $R^2$ was obtained for height at withers followed by paunch girth. However, tail length, ear width, face length and ear length yielded poor $R^2$ values which indicated that the body weight is the not dependent on these traits. Maximum $R^2$ value of 56.96 % was obtained when all the variables were included in regression equation. The best prediction equation from single trait regression was for body height at weathers Y = -17.06 + 2.008 BH with 38.50 accuracy (Eq. No. 8). The adult body weight can also be predicted with only two variables HG and BH with

46.86 % accuracy (Eq. No. 7) with slight compromise in coefficient of determination. It was observed that the height at withers was the most important and reliable indicator in live weight estimation for Kashmir Merino sheep. However, Tadesse and Gebremariam (2010) in Highland, Musa et al. (2012) in Sudanese Shogur, Ravimurugan et al. (2013) in Kilakarsal sheep and Kumar et al. (2018) in Harnali sheep reported heart girth as indicator in live weight estimation.

## CONCLUSION

The correlations of body weight with body measurements indicated that body measurements can be used to predict body weight in sheep when weighing scales may not be available under field conditions. This also indicates a high correlation between traits and therefore can be used for making selection decisions. Height at withers alone or combinations with measurements can be used with 38.50 to 56.96 % accuracy for predicting the body weight in Kashmir Merino sheep.

## ACKNOWLEDGEMENTS

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHORS CONTRIBUTION

Mubashir Ali Rather, Imran Bashir performed data analysis; Ambreen Hamdani, and M. Nazki wrote the manuscript; Nusrat Nabi Khan and Showkat A. Ahangar collected data.

## REFERENCES

• Bakhshalizadeh S, Hashemi A, Gaffari M, Jafari S, Farhadian H (2015). Estimation of genetic parameters and genetic trends for biometric traits in Moghani sheep breed. Small Rum. Res. 134: 79–83. https://doi.org/10.1016/j.smallrumres.2015.12.030

• Birteeb PT, Peters SO, Yakubu A, Adeleke MA, Ozoje MO (2012). Multivariate characterisation of the phenotypic traits of Djallonke and Sahel sheep in Northern Ghana. Trop. Anim. Health Prod. 45: 267-274. https://doi.org/10.1007/s11250-012-0211-4

• Borg RC, Notter DR, Kott RW (2009). Phenotypic and genetic associations between lamb growth traits and adult ewe body weights in western range sheep. J. Anim. Sci. 87:3506-3514. https://doi.org/10.2527/jas.2008-1622

- Fadare AO, Peters SO, Adedeji TA, Ozoje M O (2014). Genetic and phenotypic parameter estimates of body morphometric traits of West African dwarf lambs in a humid tropical environment. Trop. Agric. 91 (3) :165.
- Hamadani A, Ganai NA, Rather MA, Raja TA, Shabir N, Ahmad T, Shanaz S, Aalam S, Shabir M (2020). Estimation of genetic and phenotypic trends for wool traits in Kashmir Merino sheep. Indian J. Anim. Sci. 90(6): 893–897
- Hamadani A, Ganai NA, Khan NN, Shanaz S, Ahmad T (2019). Estimation of genetic, heritability, and phenotypic trends for weight and wool traits in Rambouillet sheep. Small Rumin. Res. 177: 133-140. https://doi.org/10.1016/j.smallrumres.2019.06.024
- Harvey WR (1990). Mixed model least squares and maximum likehood computer program, Columus, O.H. pp.1-21. Islam, M. R., Saadullah, A. R., Howlider, M.A.R. and Huq, M. A. (1991). Estimation of live weight and dressed carcass weight from different body measurements in goats. J. Anim. Sci. 61(4): 460-461.
- Jafari SHashemi A (2014). Estimation of genetic parameters for body measurements and their association with yearling liveweight in the Makuie sheep breed. S. Afr. J. Anim. Sci. 44 (2): 141–147. https://doi.org/10.4314/sajas.v44i2.6
- Khan NN, Ganai NA, Alam S, Shanaz S, Hamadani A, Rather MA, Bukhari S, Shah RM, Jalal H, Wani N. Genetic evaluation of growth performance in Corriedale sheep in J&K, India. Small Rumin. Res. 192: 106197. https://doi.org/10.1016/j.smallrumres.2020.106197
- Kumar S, Dahiya SP, Malik ZS, Patil CS (2018). Prediction of body weight from linear body measurements in sheep. Indian J. Anim. Res. 2018(52):1263-1266. https://doi.org/10.18805/ijar.B-3360
- Lalit, Malik ZS, Dalal DS, Patil CS, Dahiya SP (2016). Genetic studies on growth, reproduction and wool production traits of Harnali sheep. Indian J. Anim. Res. online published. DO1:10.18805/ijar. 10984. https://doi.org/10.18805/ijar.10984
- Mandal A, Dass G, Rout PK, Roy R (2010). Genetic parameters for direct and maternal effects on post-weaning body measurements of Muzaffarnagari sheep in India. Trop. Anim. Health Prod. 10: 9752–9756.
- Musa AM, Idam NZ, Elamin KM (2012). Regression analysis of linear body measurements on live weight in Sudanese Shugor Sheep. Online J. Anim. Feed Res. 2(1): 27-29.
- Panda P, Rao PK, Kumar P, Bhujabal BN (2014). Characterization of mutton type indigenous sheep of Puri district in Odisha. Indian J. Small Rumin. 20(1): 95-97.
- Petrovic MP, Petrovic VC, Muslic RD, Iliæ Z, Spasiæ Z, Stojkoviæ J, Makshimovic N (2012). Genetic and phenotypic of the body measured traits in Merinolandschaf breed of sheep. Biotechnol. Anim. Husband. 28(4): 733-741. https://doi.org/10.2298/BAH1204733P
- Rather MA, Kuthu B, Hamadani A, Ahanger S, Baba MA, Baba JA, Shah MM (2020). Effect of non-genetic factors on survivability and cumulative mortality of Kashmir merino lambs. Indian J. Small Rumin. 26 (I): 22:26. https://doi.org/10.5958/0973-9718.2020.00011.2
- Ravimurugan T, Thiruvenkadan AK, Sudhakar K, Panneerselvam S, Elango A (2013). The estimation of body weight from body measurements in Kilakarsal Sheep of Tamil Nadu India. Iranian J. Appl. Anim. Sci. 3(2): 357-360.
- Ravimurugan TAK. Thiruvenkadan K, Sudhakar S, Panneerselvam, Elango A (2015). The Estimation of Body Weight from Body Measurements in Kilakarsal Sheep, India. Iranian J. Appl. Anim. Sci. 3(2): 357-360
- Riva J, Rizzi R, Marelli S, Cavalchini G (2002). Body measurements in Bergamasca Sheep. Small Rumin. Res. 221-227. https://doi.org/10.1016/j.smallrumres.2003.12.010
- Sharaby MA, Sulleiman IO (1987). Factors influencing meat production traits and their association with body weight dimensions. Word Review. Anim. Prod. 23(4): 86-88.
- Snyman MA (2012). Genetic analysis of body weight in South African Angora kids and young goats. South African J. Anim. Sci. 42(2): 146-155. https://doi.org/10.4314/sajas.v42i2.7
- Sowande OS, Sobola OS (2008). Body measurements of West African dwarf sheep as parameters for estimation of live weight. Trop. Anim. Hlth. Prod. 40(6): 433-9. https://doi.org/10.1007/s11250-007-9116-z
- Tadesse A, Gebremariam T (2010). Application of linear body measurements for live body weight estimation of Highland Sheep in Tigray Region. North-Ethiopia. J. The Dry lands. 3(2):203-207
- Thiruvenkadan AK (2005). Determination of best-fitted regression model for estimation of body weight in Kanni Adu kids under farmer's management system. Livest. Res. Rural Dev. 17: 160-165.
- Verma SK, Dahiya SP, Malik ZS, Patil CS, Patil HR (2016). Biometrical characterization of Harnali sheep : A new synthetic strain. Indian J. Vet. Res. 25(1):16-21.
- Waheed A, Khan MS, Ali S, Sarwar M (2011). Estimation of growth curve parameters in Beetal goats. Arch. Tierzuch. 54:287-296. https://doi.org/10.5194/aab-54-287-2011