



# Growth Traits as Predictors of Body Weight in Sheep: A Review

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## ABSTRACT

The sheep production industry affects most rural areas and communal farm enterprises in the tropics and sub-tropics as a source of income. The motivation behind the present literature review was to provide detailed literature from various sources on the estimation of body weight from the growth traits of sheep. The review was conducted to highlight the importance of body weight and the significance of growth traits (heart girth, withers height, body length, sternum height, and rump height) as parameters to predict body weight. The main reason for livestock practice is to ensure food security. Therefore, it is important to assess economic traits and determine the carcass merit of sheep. Linear body measurement is a practical, fast, easy, and cheap method broadly utilized in national breeding programs to predict body weight and improve meat productivity in rural areas. The current review indicated that growth traits could be used to predict the body weight of sheep since they importantly provide necessary information about the morphological structure and potential development of the animals.

**Keywords:** Body length, Body weight, Growth trait, Heart girth, Rump height, Withers height

## INTRODUCTION

Sheep production in South Africa is a wide-growing livestock industry in the husbandry systems (Meissner et al., 2013). Some major economic factors related to this industry include ensuring efficient economic production through management practices focusing on shortening breeding production. Cannas et al. (2019) believe that the sheep production industry affects the economic resources in most rural areas and communal farm enterprises in the tropics and sub-tropics worldwide (Gökçe and Atakışıl, 2019). According to Ayichew (2019), sheep are primarily raised for consumption (meat and milk) and their skin for clothing and belts. Additionally, these animals are used in traditional rituals or given as gifts during ceremonies such as weddings.

The livestock industry aims to ensure food security, which can be achieved by assessing important economic traits and determining their carcass merit and value (Agamy et al., 2015). Body weight is the foremost consideration in the animal industry for marketing purposes. Additionally, understanding an animal's body weight is crucial for appropriate feeding, medication, and breeding practices (Abbas et al., 2021). In the animal industry, growth traits, such as body weight and linear body measurements, are the primary concerns during breeding for the economy, especially meat production (Moradian et al., 2013).

The sheep production industry should try to maximize production since customers have a high demand for heavier sheep (Kumari et al., 2014). Due to the lack of measuring scales, such as weighing scales in rural areas, rural farmers rely only on animal physical appearance and body weight estimates, leading to poor decision-making on medical dosing, selling, feeding, and selection criteria (Abdel-Mageed and Ghanem, 2013). Compared to visual observations and breeding value, Kumar et al. (2017) state that accurate techniques are used daily to improve growth traits, and the use of linear body measurements to predict body weight is a practical, fast, easy, and cheap method widely utilized in national breeding programs to improve the productivity of meat mostly by rural area farmers.

The motivation behind the present study was to provide a detailed review of literature from various sources on the estimation of body weight regarding sheep body parameters to enrich the literature and provide a deep understanding of this concept. In this regard, the significance of body weight is explained. Then, the importance of growth traits and body parameters, such as heart girth, withers height, body length, sternum height, and rump height, in the prediction of body weight as the primary purpose of the study is clearly explained.

### Significance of body weight

According to Akpa et al. (2011), growth is determined as the total sum of structural body components that could be measured by body parameters and live weight and is mainly considered in the livestock industry animal husbandry.

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Body weight is an important parameter for selecting animals for various purposes, such as breeding and marketing (Lakew et al., 2017).

Animal breeding practices aimed to improve the economy. Body weight is an economically important trait in the quantitative selection of animals for breeding and maximizing production (Kumar et al. 2017). Dekhili and Aggoun (2013) indicated that body weight is the most significant trait in meat industries, where breeders select Ettawa sheep of high body carcass weight to breed for the next generation. According to Shirzeyli et al. (2013), body weight could be used to monitor animal growth and make good decisions for choosing male and female replacements by determining the value of animals and the rearing efficiency. Moreover, knowledge of animal body weight assists breeders in knowing breeding regarding carcass production per animal (Iqbal et al., 2013; Yilmaz et al., 2013).

Kumar et al. (2017) reported body weight as the most important feature of economic growth. Some rural farmers are still disadvantaged when selling their sheep due to a lack of weighing scales. Tsegaye et al. (2013) found that knowledge of animal weight helps the estimation of the market price to avoid selling the animals or their product at a price they do not deserve. Chitra et al. (2012) also agree and mention that sheep body weight helps in determining the correct drug dosage, while Asefa et al. (2017) indicate that knowledge about the body weight of small ruminants plays a role in ensuring proper management of feeding and avoiding obesity and anorexia. Recent studies showed that body parameters serve either to supplement body weight as an estimate of production or as a predictor of some less visible traits (Dekhili and Aggoun, 2013). According to Babale et al. (2018), the most reliable traits to estimate live body weight are wither height, body length, heart girth, rump height, and width. Moreover, they can also be used as indicators of breed origin and relationships within species.

As reported by Prasad (2010), knowledge about the body weight of goats, sheep, and pigs is important for the computation of balanced ratio, evaluation of growth, and health management. Birteebi and Ozoje (2012) documented that precise body weight could guarantee that farmers or producers were well repaid for their hard work and investments when raising the West African long-legged and West African dwarf sheep. Animal breeding practices aim to improve traits of economic importance, such as body weight, for better selection and production improvement (Shirzeyli et al., 2013).

### **Significance of growth traits as parameters to predict body weight**

Prediction of body weight from linear body measurements is the simple, cheap, and best method, especially in communal areas where they lack resources, such as weighing scales, to determine the body weight of their animals (Sandeep et al., 2017). According to Younas et al. (2013), the livestock and meat industry aims to have an accurate and objective measurement method for improving traits and predicting the weight, values, and merit of the carcass of the live animal at a low cost. Moreover, Asefa et al. (2017) added that linear body measurements could be used indirectly to determine body weight as they are easy and simple to measure. Body linear measurements are the quantitative traits of carcass or meat and assist in developing selection criteria based on farmers' objectives (Kumar et al., 2017).

The primary aim of the animal industry is to have a technique that can accurately measure, access traits of economic importance, and establish animal merit and value of the carcass when the animal is alive (Agamy et al., 2015). One of the most popular methods for determining the relationship between two traits is a correlation between traits (Shirzeyli et al., 2013). Knowledge about the relationship between live body weight and body parameters helps the selection of superior animals in body weight in the Balochi male sheep for breeding purposes (Jahan et al., 2013).

Based on reports by Shirzeyli et al. (2013), linear body measurements differ in terms of breed, gender, and age. Many studies have been performed where body parameters are used to predict the body weight of different livestock (Babale et al. 2018). Kumar et al. (2017) concluded that body measurements serve as valuable growth indicators for sheep, particularly in rural areas where scales are scarce, aiding in the estimation of body weight and carcass characteristics. Birteeb et al. (2012) added that they have been used by other authors to predict body weight in exotic sheep breeds. As stated by Kumar et al. (2017), linear body measurement in livestock is a tool for farmers to recognize the morphological genetic strengths and weaknesses of sheep. Furthermore, body measurements can indirectly give an accurate estimate of body weight, especially when measured in the morning before the time sheep are released to graze or given feeds. According to Lakew et al. (2017), body measurements are key data sources for reflecting the breed standards and can also be used as qualitative growth indicators that reflect animal body changes during the animal's lifetime.

Knowledge of the correlation between body weight and linear body parameters is vital for better improvement and management in terms of adequate medicine administration and feed supply (Mohammad et al., 2012). Body traits are important when selecting superior indigenous Mengali sheep to gain more genetic progress in reproductive yield (Tariq et al., 2012).

According to Verma et al. (2016), linear body measurements detail the skeletal structure, growth, and development

capability of the Harnali sheep. Body parameters have been used to predict body weight in many sheep breeds (Younas *et al.*, 2013). A study by Shirzeyli *et al.* (2013) indicated that linear body parameters provide information about the morphological structure and potential for development in Iranian sheep. Additionally, linear body parameters, such as rump height, withers height, body length, and heart girth, could be considered to predict body weight (Olawumi and Farinnako, 2017).

The capacity and skill of producers and purchasers to understand linear body measurements to growth traits are important in increasing production (Babale *et al.*, 2018). As reported by Kumar *et al.* (2017), body measurements in sheep are used to evaluate the quantitative traits of meat. Eghahi *et al.* (2011) added that body measurements had been used in predicting body weight and helping in setting appropriate meat prices. Berhe (2017) highlighted that linear body measurements, mostly in smallholder farmers, could sustain the improvement of indigenous sheep. Common traits used for breed improvement are body length, heart girth, and withers height. As confirmed by Weldeyesus and Yaynesht (2016), the aforementioned body measurements are critical traits used for selecting and improving commercial goats. Many researchers have studied these traits as predictors of body weight in small livestock, including sheep and goats (Eyduran *et al.*, 2017).

### **Heart girth**

Heart girth is measured as the body circumference around the chest just behind the front legs and withers (Kumar *et al.*, 2017). Most studies have revealed that heart girth could be used to predict body weight in different livestock and give reasonably accurate results. Body weight was predicted from linear body measurements in Awassi Crossbred sheep in a study conducted by Lakew *et al.* (2017). The findings indicated a highly significant relationship between body weight and heart girth, implying that heart girth impacts body weight and that improving heart girth might result in improved body weight. Kumar *et al.* (2017) reports agree with the above results. Their results showed that body weight could be predicted by heart girth. Therefore, heart girth could be used as the independent trait to estimate body weight in rural areas, where they lack weighing scales, and can also be used as a trait for the development and improvement of Harnali sheep.

In West African Dwarf goats, the correlation between body weight and linear body measurements was evaluated, and heart girth was revealed to have a strong relationship with body weight despite gender and location (Olawumi and Farinnako, 2017). A study by Younas *et al.* (2013) on Hissardale sheep showed that when body length, height at withers, and heart girth increase in the early stages of an animal's life, body weight increases, as well. Body weight in three Egyptian Fat-tailed sheep was estimated using linear body measurements, and a significant relationship between heart girth and body weight was found in Barki sheep Agamy *et al.* (2015). Furthermore, Abd-Alla (2014) considers heart girth a reliable predictor of body weight.

In their study on Jamuna basin sheep of Bangladesh across various age groups, Sun *et al.* (2020) found that heart girth was statistically significant in the 1-9 months group and 1-2 years group, correlating strongly with body weight. This positive relationship suggests that heart girth can be used effectively to estimate and potentially enhance body weight. Similar findings were reported in studies involving animals aged 2-6 years (Yilmaz *et al.*, 2013), indicating the reliability of heart girth in estimating body weight across different age ranges. Moreover, a study focusing on sheep aged 13-24 months identified heart girth as the most effective trait for estimating body weight. This correlation implies that Nigerian sheep breeds with larger heart girth tend to have higher body weights (Mahmud *et al.*, 2014).

Linear body parameters have been used to estimate body weight by some workers in exotic sheep breeds (Birteeb *et al.*, 2012). Research by Kumar *et al.* (2017) described heart girth as the most important trait, and it was observed to be the trait that can be used to estimate body weight, especially in rural areas where weighing scales are absent. Similar suggestions were reported by Petrovic *et al.* (2012) and Jafari and Hashemi (2014) using different sheep breeds. According to Kumar *et al.* (2017), farmers who lack a weighing scale can use heart girth as a predictor of body weight. Prasad (2010) conducted a study and stated that body parameters, such as heart girth, are commonly used in estimating body weight in small ruminants, such as goats, sheep, and pigs.

### **Body length**

According to Babale *et al.* (2018), body length is measured from the occipital protuberance to the base of the tail. Body parameters, such as body length, can be used to evaluate quantitative traits of meat, and it is easy to measure. It can be used as an indirect way to predict live weight and carcass traits (Agamy *et al.*, 2015). Shirzeyli *et al.* (2013) conducted a study involving four sheep breeds and found that certain linear body measurements, such as body length, could predict body weight specifically in the Shaal breed. The relationship between animal body measurements and body weight varies depending on factors like breed, sex, and age, offering insights into their growth and development (Tariq *et al.*, 2012). In another study focusing on sheep, Shirzeyli *et al.* (2013) highlighted a strong correlation between

body length and body weight. Similarly, Kumar et al. (2017) reported a positive statistical relationship between body weight and body length from a study conducted on Harnali sheep.

In indigenous sheep populations of Southern Ethiopia study by Melesse et al. (2013), the body length of Sidama-Gedeo, Wolaita, KmabataTembaro-Hadiya, and Gamogofa ewe had a high positive statistical correlation with body weight. A study on highland sheep in Tigray in Ethiopia by Berhe (2017) showed that body length in areas with no weighing scales could predict body weight due to a high positive correlation with body weight.

### **Wither height**

As stated by Agamy et al. (2015), the wither height of an animal is the distance from the bottom of the front foot (phalanges) to the highest point of withers between the shoulders and is measured when the animal is standing. A study on indigenous sheep breeds showed a positive relationship between wither height and body weight (Mohammad et al., 2012).

Jahan et al. (2013) documented that withers height is a statistically significant trait related to body weight, suggesting that an increase in withers height could lead to an increase in body weight. Shirzeyli et al. (2013) studied four different breeds, namely Mehrabani, Macoei, Zandi, and Shaal. The results showed that withers height could be used to predict body weight in the Shaal breed; however, it was not significant in other breeds. In Ossimi and Rahmani ramlams, Agamy et al. (2015) outlined that withers height was correlated to body weight. The results are in line with Shehata (2013), who stated that body weight and withers height had a highly significant relationship.

Linear body measurements of Kashmir Merino Sheep were used as predictors of body weight by Rather et al. (2021), and a positive phenotypic correlation was observed between body weight and all the traits in the study. Wither height was the best predictor of body weight in that study. Genetic and phenotypic relationships between various body measurements were found by Petrovic et al. (2012) in Merino lands chaf sheep, Jafari and Hashemi (2014) in the Makuie sheep breed, and Kumar et al. (2017) in Harnali sheep. Additionally, wither height correlated to body weight in a study conducted by Mahmud et al. (2014) in 37 months and in different sheep age groups.

Different linear body measurements and prediction equations for the live weight of indigenous sheep populations in southern Ethiopia were studied, and withers height had a positive statistical relationship with body weight in Wolaita and Sidama-Gedeo ewes aged 1-2 years (Melesse et al., 2013). In rams, a significant relationship was also found between body weight and body length

### **Sternum height**

Tyasi et al. (2020) reported sternum height as the vertical distance from the lower tip of the sternum to the ground in standing animals in the Nguni cattle breed. Prediction of body weight from body parameters was reported by Sun et al. (2020). The study revealed a correlation coefficient between body weight and sternum height among sheep aged 1-9 months, indicating that these sheep tended to have higher body weights compared to other breeds like Dorper. Furthermore, Temoso et al. (2017) conducted a study in Botswana on both sheep and goats, disregarding sex. Sternum height was also found to have the highest correlation with body weight, and the results are consistent with those of Norris et al. (2015) on indigenous goats.

Correlation and path analysis of body weight and biometric traits of Nguni cattle breed study by Tyasi et al. (2020) confirmed sternum height as the best predictor of body weight. Yilmaz et al. (2011) described sternum height as the distance between the height point of the wither and the ground. Their results on Kangal Type Akkaraman sheep revealed sternum height could be a candidate trait for estimating body weight. Patbandha et al. (2018) findings also state that sternum height could be used to predict body weight.

In a study on Female Etawah Grade Goats, Dakhlan et al. (2020) found that body weight correlated with sternum height. Similarly, Baleseng et al. (2016) conducted research on goats and sheep, indicating that shoulder height is statistically significantly correlated with animal weight. These findings suggest that shoulder height can potentially serve as a predictor of weight in both goats and sheep. These reports suggest that shoulder height can potentially be a predictor of weight in both goats and sheep. The study by Musa et al. (2012) showed heart girth is a better proxy measure of weight than shoulder height; however, both can be used to estimate the weight of goats and sheep under communal grazing.

### **Rump height**

Based on Olawumi and Farinnako (2017), rump height is measured as the distance from the surface of a platform to the rump in a standing West African Dwarf Goat. A study by Sun et al. (2020) indicated that rump height had a high statistical relationship with body weight in 1 to 2 years of age Jamuna sheep. Lavvaf et al. (2012) and Melesse et al. (2013) findings are in agreement with results obtained from Jamuna sheep that body weight has a strong positive

relationship with rump height (Berhe, 2017).

Deribe *et al.* (2018) used correlational analysis to estimate the relationship between two variables. Linear body measurements of Begait, Gumz, and Rutana sheep were used to estimate body weight. Results showed a positive correlation between body weight and some linear body measurements, with rump height as one of the traits in Begait, Gumz, and Begait sheep, rump height was found to be the trait statistically correlated to body weight. Asefa *et al.* (2017) report on indigenous sheep of the Bale zone agrees with the above findings by Deribe *et al.* (2018).

Mahmud *et al.* (2014) documented a study on the estimation of body weight using cannon bone length and other body measurements in Nigerian breeds of sheep. Body weight was correlated to rump height as one of the linear body measurements in sheep under 12 months of age. Lavvaf *et al.* (2012) found similar results in a study conducted on sheep. Özen *et al.* (2019) report on Awassi sheep showed rump height was the most accurate trait to predict body weight. Ambacioğlu *et al.* (2017) added that linear body measurements could help farmers estimate their livestock's body weight for management purposes, and rump height appeared to be the best candidate to be used to estimate body weight.

### **Prediction methods for weight measurement**

The regression analysis method is the most widely used in multivariate statistical analysis to estimate the association between dependent and independent variables (Mohammad *et al.*, 2012). A study by Mokoena *et al.* (2022) reveals that classification and regression trees are the optimum models with body length as the essential linear body measurement for estimating the body weight of Kalahari Red goats. Multivariate adaptive regression splines showed that age and wither height influenced the body weight in Nguni cows. In contrast, the results obtained from the regression tree data mining algorithm indicated that body length played a significant role in the body weight estimation of Nguni cows in the study conducted by Hlokoe *et al.* (2022). Additionally, it was noted that marker-assisted selection is the best-fit model for estimating body weight in Nguni cows.

Mathapo (2022) utilized data mining algorithms to analyze South African non-descript indigenous goats, concluding that body length alone could predict body weight based on a chi-square automatic interaction detector and classification and regression tree methods.

Avijit *et al.* (2022) employed recursive partitioning and regression trees (RPART) and stepwise regression model tools to predict body weight using linear body measurements, RPART, and stepwise regression models indicated that heart girth influenced live weight. Mohammad *et al.* (2012) estimated body weight from withers height, body length, and chest girth measurements using the Regression Tree (RT) Method. Statistically significant correlation coefficients were detected between body weight and wither height.

## **CONCLUSION**

The present review indicated the use of growth traits as the most convenient method for estimating body weight, especially for farmers who lack weighing scales to determine the weight of their animals for breeding, nutrition, marketing purposes, and health management. Body length, heart girth, and wither height are popular traits for sheep breeds. However, more studies need to be conducted to predict body weight using more linear body measurements and other growth traits on different breeds to provide more information on improving the growth of the small stock.

## **DECLARATIONS**

### **Availability of data and materials**

Datasets and materials generated during the current study are available at the University of Limpopo and are accessible from the corresponding author upon reasonable request.

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### **Ethical considerations**

Consent to publication and misconduct, plagiarism, data fabrication and double submission of the manuscript, and redundancy and other ethical issues were checked by the authors.

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### Authors' contributions

Molabe Kagisho Madikadike and Tyasi Thobela Louis designed the study, Molabe Kagisho Madikadike wrote the review, and Tyasi Thobela Louis proofread the review. All authors confirmed the last content of the article before publication.

### Competing interests

There is no competing interest to declare.

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