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Phenotypic Indicators for Pro-Poor Animal Breeding: The Role of Linear Body Measurements in Genetic Improvement of Indigenous Chickens and Livestock in Sub-Saharan Africa

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Abstract

Linear body measurements (LBMs) have indeed been referred to by various terms across scientific literature, depending on the context, species studied, or regional preferences. In Sub-Saharan Africa, where access to advanced animal breeding technologies is limited, traditional genetic improvement strategies face considerable challenges. This paper explores the utility of linear body measurements (LBMs)—including traits like heart girth, body length, and wither height—as effective proxies for complex performance metrics in indigenous livestock and poultry. These morphometric traits provide a low-cost, scalable alternative for estimating live weight, growth potential, and reproductive performance, especially in smallholder production systems lacking digital scales or genomic tools. LBMs are particularly valuable due to their ease of measurement and non-invasive nature, making them ideal for community-based breeding initiatives. Research consistently reports moderate to high heritability estimates for many of these traits, with strong phenotypic and genetic correlations linking them to key outcomes such as body weight, carcass quality, and fertility. For example, heart girth has proven to be a reliable predictor of live weight in goats, sheep, and cattle, while traits like shank and keel length are commonly used in indigenous poultry selection. The paper highlights that non-genetic influences—including age, sex, nutrition, and production environment—must be accounted for when applying LBMs in breeding programs. Age-related growth patterns, sex-based dimorphism, and feed availability can significantly alter body dimensions and, if unadjusted, may confound genetic evaluations. In addition to supporting phenotypic selection, LBMs contribute to breed characterization and management of indigenous genetic resources. When combined with emerging genomic tools, these measurements can enhance the accuracy of estimated breeding values and facilitate targeted interventions such as artificial insemination. They also offer an entry point for digitized data collection systems, making them adaptable to evolving breeding infrastructures. Overall, the integration of LBMs into livestock improvement programs represents a pragmatic approach to enhancing productivity, resilience, and food security in resource-constrained settings. To maximize their impact, stakeholders should invest in standardizing measurement protocols, training local actors, and aligning LBM use with broader genetic improvement and conservation efforts across the region.

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1. Introduction

Accurate estimation of body weight and growth performance in livestock is critical for selection and breeding programs. In resource-poor regions, zoometrical measurements—such as body length, height at withers, and heart girth—serve as effective proxies for predicting live weight and assessing breed characteristics (Yakubu *et al.*, 2017; Mohammed *et al.*, 2021). While

advanced genomic tools have revolutionized livestock improvement in high-income countries, their limited availability and cost remain significant barriers in developing nations. Consequently, integrating phenotypic measurements into breeding programs offers a practical and scalable solution (Bello *et al.*, 2020; Tadesse *et al.*, 2023)^[13]. These measurements have been widely used for breed characterization in species such as cattle, sheep, and goats, yet their application in genetic improvement programs remains underexplored.

Body weight is crucial for various aspects of livestock management, including breeding, feed formulation, disease diagnosis, medication dosing, market valuation, monitoring growth and productivity, and transport and welfare regulations (Tibbo *et al.*, 2021; Moyo *et al.*, 2023). It is essential for determining the appropriate quantity and quality of feed for maintenance, growth, reproduction, or lactation, as underfeeding or overfeeding can result in poor growth performance, economic loss, or metabolic disorders (Abegaz & Mekasha, 2020; Dube *et al.*, 2024)^[2]. Accurate weight estimation also ensures optimal rationing and feed efficiency, especially in resource-limited settings where feed costs are a major expenditure (Chimonyo & Mapiye, 2022). Inaccurate estimation of weight compromises animal health and welfare (Ogola *et al.*, 2021). Accurate weight assessment improves transparency in transactions and ensures fair pricing, benefiting both producers and buyers (Ndlovu *et al.*, 2023). Regular weight measurements also enable farmers to track growth rates and detect deviations that may indicate health or nutritional problems (Zewdu *et al.*, 2020; Kamau *et al.*, 2025).

Linear body measurements are not only easy to obtain, even under field conditions, but also show strong associations with economically important traits such as live weight, body condition score, and carcass yield (Yakubu *et al.*, 2020; Wondmeneh *et al.*, 2022). These measurements, including heart girth, body length, and wither height, are practical proxies for predicting body weight in situations where weighing scales are unavailable or unaffordable (Mwambene *et al.*, 2021; Musa *et al.*, 2023). Their moderate to high heritability makes them useful as indirect selection criteria in genetic improvement programs (Yussif *et al.*, 2024). The heritable nature of these traits implies that selective breeding based on zoometrical indices can bring about cumulative genetic gains across generations, improving the overall performance of livestock and poultry populations (Kebede *et al.*, 2020; Abegaz *et al.*, 2023)^[2].

Several recent studies have reported significant genetic and phenotypic correlations between zoometrical traits and production metrics, such as growth rate, feed efficiency, reproductive traits, and meat quality (Ngeno *et al.*, 2021; Worku *et al.*, 2022). This relationship enables the use of simple, non-invasive measurements in marker-assisted and phenotypic selection frameworks, reducing the costs of breeding operations in resource-limited environments. In particular, the integration of these traits into community-based breeding programs offers a practical approach for improving local breeds adapted to harsh environments while retaining their resilience traits (Tibbo *et al.*, 2021; Mapiye *et al.*, 2025).

Moreover, the use of zoometrical measurements supports food security efforts by enhancing livestock productivity,

improving household incomes, and strengthening the genetic base of indigenous animal populations in developing countries (Chimonyo & Bhebhe, 2020; Ayele *et al.*, 2024). This review highlights the transformative potential of zoometrical measurements in breeding strategies for poultry and livestock, particularly in Sub-Saharan Africa, where access to advanced weighing and recording technologies remains limited. Their strategic use can thus serve as a foundation for sustainable genetic improvement, increased productivity, and resilience in the face of climatic and economic challenges.

2. Materials and Methods

2.1. Study Design

This study employed a systematic review approach to synthesize existing scientific literature on the relationship between zoometrical (linear body) measurements and performance traits for genetic improvement of indigenous poultry and livestock in developing countries. The review adhered to the Preferred Reporting Items for Systematic Reviews guidelines to ensure transparency, replicability, and scientific rigor (Page *et al.*, 2021).

2.2. Literature Search Strategy

A comprehensive search was conducted across multiple electronic databases, including Web of Science, Scopus, PubMed, CAB Direct, and Google Scholar, covering studies published between 2015 and 2025. Search terms were developed using Boolean operators and included combinations of the following keywords, following established systematic search strategies (Bramer *et al.*, 2018)^[18].

- “zoometric measurements” OR “linear body measurements”
- AND “performance traits” OR “growth traits” OR “reproductive traits”
- AND “genetic improvement” OR “selection”
- AND “indigenous livestock” OR “indigenous poultry”
- AND “developing countries” OR “Sub-Saharan Africa”

Additional literature was retrieved through manual searches of references cited in relevant review articles and primary studies.

2.3. Inclusion and Exclusion Criteria

- Studies were included if they met the following criteria:
- Published in peer-reviewed journals between 2015 and 2025.
- Focused on indigenous poultry or livestock breeds in developing countries.
- Reported statistical relationships between zoometrical measurements and performance traits (e.g., weight gain, fertility, milk yield).
- Provided sufficient methodological detail for assessment of validity.

2.4. Exclusion criteria

- Studies focusing exclusively on exotic or crossbred animals.
- Articles not written in English.
- Conference abstracts, theses, and unpublished grey literature unless they provided robust data.

2.5. Data Extraction and Management

Relevant data were independently extracted by two reviewers using a standardized data extraction form, following recommended best practices for systematic reviews (Higgins *et al.*, 2022)^[36]. Information collected included:

- Study location and species studied
- Sample size and breed(s) involved
- Types of zoometrical measurements used
- Performance traits evaluated
- Statistical methods applied
- Key findings and reported genetic or phenotypic correlations
- Any discrepancies were resolved through discussion or by consulting a third reviewer.

2.6. Quality Assessment

Each study was evaluated for methodological quality using a modified version of the Critical Appraisal Skills Programme (CASP) checklist. Evaluation criteria included clarity of research objectives, appropriateness of study design, validity of measurement techniques, and statistical rigor. Based on these criteria, studies were classified as high, moderate, or low quality. Only studies rated as high or moderate were included in the synthesis, while low-quality studies were excluded (Singh *et al.*, 2021; Moola *et al.*, 2020; CASP, 2023)^[20].

3. Results and Discussion

3.1. Conceptualizing Linear Body Measurements in Animal Breeding and Production

Linear body measurements (LBMs) are referenced under a variety of synonymous terms throughout animal science literature, reflecting variation in disciplinary focus, species studied, and methodological context. Commonly encountered alternatives include *zoometrical traits*, which pertain specifically to externally observable morphological characteristics (Yakubu *et al.*, 2020), and *morphometric traits*, a term extensively employed across both livestock and wildlife studies to describe body shape and structural dimensions (Dossa *et al.*, 2021). Closely related nomenclature includes *body conformational traits* or *conformation traits*, which underscore structural attributes relevant to functional efficiency and adherence to breed standards (Ali *et al.*, 2021; Tadesse *et al.*, 2023), as well as *phenotypic body traits* or *external body traits*, which denote visible, measurable features of the animal phenotype (Jembere *et al.*, 2021). The more inclusive term *anatomical measurements* encompass both internal and external body dimensions (Abegaz *et al.*, 2022)^[2].

In the context of applied breeding programs, phrases such as *body size descriptors* and *body dimensions* are commonly used (Mwangi *et al.*, 2023), whereas *skeletal traits* or *skeletal frame traits* are more specific to measurements of the animal's osseous structure, including stature, body length, and wither height (Yilmaz *et al.*, 2018; Ibrahim *et al.*, 2023)^[37]. Older or geographically localized studies often refer to these parameters as *biometric traits* (Bello *et al.*, 2020)^[13]. Within dairy cattle improvement programs, the term *type traits* are frequently applied to describe morpho-functional features associated with productivity, such as udder conformation, teat placement, and overall body form (Gernand *et al.*, 2019; Akin, 2016)^[30]. Regardless of the nomenclature, all these terms converge on the central concept

of quantifiable morphological attributes that are indispensable for phenotypic evaluation, genetic selection, and performance forecasting.

3.2. Genetic Parameters of Linear Body Measurements

Heritability estimates provide insight into the proportion of trait variation attributable to genetic factors. Studies across species show moderate to high heritability for linear measurements, making them valuable traits in selection programs. For instance, heritability of body weight in broiler chickens has been reported as 0.38–0.46, indicating substantial potential for genetic gain (Sanda *et al.*, 2014). Studies in poultry and livestock have reported low to moderate heritability for linear body traits, often influenced by additive gene action, sample size, and maternal effects. Linear body measurements are essential indicators of growth, productivity, and reproductive potential in livestock. Recent studies have provided updated heritability estimates and genetic correlations for these traits across various species. The genetic basis of linear body measurements is essential for livestock improvement, particularly in the context of selection and crossbreeding. Heritability (h^2), defined as the proportion of phenotypic variance attributable to genetic variance, serves as a key indicator of a trait's potential for genetic improvement. Generally, heritability estimates for linear body traits vary widely across species and breeds, reflecting the influence of both genetic and environmental factors.

For instance, Sanda *et al.* (2014) observed heritability estimates for body weight in broiler chickens ranging from 0.26 to 0.46, with strong positive correlations between body weight and linear measurements. In rabbits, very high heritability estimates were reported for traits such as body length and ear length, suggesting strong genetic control and high potential for improvement through selection (Chineke & Adeyemi, 2001). However, inconsistencies such as negative variance components have been observed, possibly due to estimation limitations or negligible additive genetic variance. In breeds such as Jamunapari goats, modest heritability values (0.14–0.20) for key morphometric traits imply that while environmental factors influence early development, genetic selection can still drive progress when sustained over generations. High genetic correlations between live weight and these linear measurements suggest that selection based on body measurements can effectively improve growth traits. In sheep, research by Abbasi and Ghafouri-Kesbi (2011) and Jafari and Hashemi (2014) using REML-based animal models indicated moderate heritability (0.11–0.36) for traits like height at withers, heart girth, and scrotal circumference. Scrotal circumference, with relatively higher heritability, also holds potential for improving reproductive performance. Similarly, scrotal circumference in rams—a trait linked to reproductive capacity—shows heritability values up to 0.50 (Duguma *et al.*, 2021)^[26]. These values support the inclusion of zoometrical traits in breeding indices to enhance meat yield and reproductive efficiency (Tadesse *et al.*, 2023). Moreover, studies have shown that including maternal genetic and environmental effects in the model improves the accuracy of heritability estimates, especially at early life stages (Mandal *et al.*, 2008).

Research on Holstein cows in Turkey reported heritability estimates for stature ranging between 0.25 and 0.53, while angularity had an estimated heritability of 0.21 ± 0.141 , indicating moderate genetic control over these linear type traits (Akin, 2016)^[6]. Similarly, a study on primiparous

Holstein-Friesian cows found heritability estimates for milk yield (0.182), fat yield (0.134), and protein yield (0.170). Linear type traits such as teat length, front teat placement, rear udder height, and udder depth showed lower heritability values, all under 0.110, suggesting a stronger environmental influence (Gernand *et al.*, 2019)^[30]. Furthermore, a study on docility and its correlation with body weight and linear body measurements in beef cattle reported very low heritability estimates for body weight (0.013 ± 0.004) and associated linear measurements (ranging from 0.001 ± 0.15 to 0.02 ± 0.20), underscoring the dominant role of environmental factors (Kim *et al.*, 2020). In Anatolian buffalo calves, direct additive heritability estimates for body weight (0.435 ± 0.040), withers height (0.539 ± 0.046), and body length were substantially high, indicating significant genetic control (Yilmaz *et al.*, 2018). Likewise, in dairy Gyr cattle, heritability estimates for cow weight at calving (0.21 ± 0.06) and 305-day milk yield (0.29 ± 0.04) reflected moderate genetic influence (Carneiro *et al.*, 2016)^[19]. Earlier studies by Berry *et al.* (2004)^[14] and Blackmore *et al.* (1958)^[17] also highlighted moderate heritability for these traits, with genetic influence increasing with age in Holstein cattle.

3.3. Some Non-Genetic Factors Influencing Linear Body Measurements

Linear body measurements are critical phenotypic indicators used in livestock and poultry research to assess growth performance, body conformation, and potential for genetic improvement. While genetic makeup plays a key role in determining these traits, a wide range of non-genetic (environmental) factors also significantly influence body dimensions. Understanding these influences is essential for accurate phenotypic characterization, effective breeding program design, and reliable genetic evaluations. Among the most reported non-genetic factors are age, sex, nutrition, agro-ecological zone, season, and management practices (Yakubu & Salako, 2016; Ajayi *et al.*, 2020). For instance, younger animals typically exhibit smaller measurements due to their ongoing growth phase, while mature individuals show more developed morphometric traits (Kebede *et al.*, 2017). Similarly, males often surpass females in body dimensions owing to hormonal and physiological differences (Mohammed *et al.*, 2018). Nutritional status plays a central role as well, with animals raised under optimal feeding regimes exhibiting superior linear body measurements compared to those under feed constraints (Tadesse *et al.*, 2021).

3.3.1. Sex-Related Variation in Linear Body Measurements

Sex is a significant non-genetic factor that influences linear body measurements (LBM) across livestock and poultry species. Sexual dimorphism—the systematic difference in size and morphology between males and females—is commonly observed and has both biological and management implications (Abegaz *et al.*, 2022; Ebegebulem *et al.*, 2023; Khandoker *et al.*, 2021; Yakubu & Salako, 2020)^[2, 27].

In cattle, males (bulls) typically exhibit larger body measurements than females (cows) due to hormonal influences, particularly testosterone, which enhances muscle development and bone growth. Bulls generally have greater body length, chest girth, height at withers, and head dimensions. These differences become more pronounced after puberty and are critical in breed characterization,

selection for breeding bulls, and performance evaluation (Ali *et al.*, 2021; Ogbu *et al.*, 2022; Tebug *et al.*, 2020; Yadav *et al.*, 2023).

Rams tend to be significantly larger than ewes in most linear body traits, including body length, chest girth, and height at withers. The sexual dimorphism in sheep is often used in breed selection, especially in meat-producing breeds, where rams with superior conformation are prioritized for genetic improvement programs (Abegaz *et al.*, 2022; Dossa *et al.*, 2021; Ibrahim *et al.*, 2023; Tefera *et al.*, 2020)^[2, 37].

Male goats (bucks) consistently outperform females (does) in terms of LBM, particularly in traits such as height at withers, body length, and heart girth. Bucks have more muscular builds and broader chests, which are advantageous for mating and defense. This difference is useful in phenotypic selection and in the estimation of genetic parameters for growth and reproductive traits (Edeh *et al.*, 2020; Tsegaye *et al.*, 2021; Yakubu *et al.*, 2023; Zergaw *et al.*, 2022)^[29].

In poultry, cocks (roosters) exhibit larger body size and dimensions compared to hens. Cocks typically have greater body length, shank length, and wingspan. This is attributable to higher anabolic activity and growth hormone levels. In indigenous chicken populations, these differences are crucial for selection and breeding programs aiming to improve growth traits or adapt birds to specific production environments (Ebegebulem *et al.*, 2023; Jembere *et al.*, 2021; Mwangi *et al.*, 2022; Olawumi & Ogunlade, 2020)^[27].

3.3.2. Nutrition-Related Variation in Linear Body Measurements

Nutrition plays a pivotal role in the development and expression of linear body measurements (LBM) in livestock and poultry. As a key non-genetic factor, nutrition influences both skeletal and muscular growth, which are directly reflected in phenotypic traits such as body length, chest girth, height at withers, and limb measurements. The quality, quantity, and consistency of nutrient intake during different growth stages determine the extent to which an animal can reach its genetic potential (Alemayehu *et al.*, 2021; Melesse *et al.*, 2023; Nwobodo *et al.*, 2020; Yakubu *et al.*, 2022)^[9].

In ruminants such as cattle, sheep, and goats, access to balanced diets rich in energy, protein, vitamins, and minerals during early growth phases results in superior body measurements. Animals raised under poor nutritional conditions—typical of extensive or low-input systems—often exhibit stunted growth, reduced chest girth, shorter body length, and lower body weight, even when genetic potential is high. Nutritional restriction during critical growth periods, such as weaning or early puberty, can have long-term adverse effects on body conformation and productivity (Abebe *et al.*, 2023; Ebiwonjumi *et al.*, 2021; Hailemariam *et al.*, 2020; Muhammad *et al.*, 2022)^[1, 28].

In poultry (hens and cocks), feed quality and composition significantly affect LBM such as shank length, keel length, and body length. Inadequate protein levels, for example, limit skeletal development and feather growth. Conversely, well-formulated diets enable birds to express optimal growth traits, improve feed efficiency, and contribute to better flock uniformity and reproductive performance (Akinola *et al.*, 2021; Deribe & Melesse, 2023; Mugisha *et al.*, 2020; Oke *et al.*, 2022)^[7, 22].

The nutritional environment also interacts with other non-genetic factors, such as age, sex, and season, compounding their effects on LBM. Moreover, animals under intensive and

semi-intensive systems tend to show better morphometric traits compared to those under extensive systems, primarily due to improved nutritional management (Haile *et al.*, 2020; Mohammed *et al.*, 2021; Osei-Amponsah *et al.*, 2023; Zergaw *et al.*, 2022).

3.3.3. Age-Related Variation in Linear Body Measurements

Age constitutes a critical non-genetic determinant of variation in linear body measurements (LBMs) across both livestock and poultry species. As animals progress through developmental stages, their skeletal and muscular systems undergo continuous transformation, manifesting in measurable changes in morphometric traits. Monitoring these age-related shifts is instrumental for accurate growth modeling, phenotypic breed characterization, and informed selection strategies. Typically, juvenile animals display comparatively smaller values for traits such as body length, height at withers, chest girth, and limb length. These dimensions progressively increase with maturation, reflecting physiological processes such as osseous extension and muscular hypertrophy. However, the trajectory and velocity of growth are not uniform across species or breeds, as they are modulated by inherent genetic potential and interacting environmental variables (Bayram *et al.*, 2021; Ibrahim *et al.*, 2023; Mesfin *et al.*, 2022; Yakubu & Musa, 2020)^[37, 12].

Linear body traits exhibit a consistent increase with advancing age until animals attain physiological maturity. Empirical studies on indigenous cattle and small ruminants indicate that morphometric parameters such as body length, chest girth, and height at withers undergo accelerated growth during the pre-weaning and immediate post-weaning phases, subsequently stabilizing as animals near adulthood. These ontogenetic patterns are particularly informative for age estimation based on morphometric data—an approach of significant utility in low-input production systems where precise birth records are often unavailable (Chala *et al.*, 2020; Ibrahim *et al.*, 2023; Tadesse & Mekasha, 2021; Zergaw *et al.*, 2022)^[37, 21].

Age-related variation in body measurements is also evident in traits such as shank length, keel length, and body depth, which typically experience rapid expansion during the early weeks of life, particularly under favorable nutritional and health conditions. Peak growth rates are generally achieved prior to sexual maturity, beyond which somatic growth decelerates as metabolic energy is reallocated toward reproductive development (Ajayi *et al.*, 2021; Deribe & Melesse, 2023; Osei-Amponsah *et al.*, 2022; Yakubu & Musa, 2020)^[5].

A comprehensive understanding of age-, sex-, and nutrition-induced variation is essential for disentangling genetic effects from environmental influences on phenotypic expression. Such knowledge facilitates standardized data acquisition, enables age-adjusted trait comparisons, and assists in identifying optimal selection windows within breeding programs. Furthermore, in the absence of birth registration systems—a common constraint in extensive livestock production—LBMs offer a practical and reliable proxy for approximating chronological age in field conditions (Ibrahim

et al., 2023; Osei-Amponsah *et al.*, 2022; Tadesse & Mekasha, 2021; Zergaw *et al.*, 2022)^[37].

3.4. Correlation Between Linear Measurements and Performance Traits

A substantial body of empirical evidence affirms the existence of strong phenotypic and genetic correlations between linear body measurements (LBMs) and economically important performance traits, including body weight, milk yield, and fertility. Morphometric parameters such as chest girth and height at withers have demonstrated a particularly robust association with live body weight in small ruminants, notably goats and sheep (Alabi *et al.*, 2019; Kerketta *et al.*, 2015)^[8]. In pigs, Morenikeji *et al.* (2013) reported a correlation coefficient of 0.83 between chest girth and body weight, further underscoring the predictive validity of this easily obtainable trait. These associations are of considerable practical value, providing a cost-effective and non-invasive basis for early selection in production systems where access to calibrated weighing equipment is limited.

Recent research has further substantiated the predictive strength of LBMs in relation to key productive attributes across various livestock species, with especially strong applicability observed in sheep and goats (Amin *et al.*, 2021; Hassen *et al.*, 2022; Mwangi *et al.*, 2023; Okpeku *et al.*, 2020; Tesfaye *et al.*, 2024). In goats, heart girth (HG) consistently emerges as one of the most reliable indicators of live body weight. For example, in indigenous goat populations of Swaziland, an exponential regression model utilizing HG alone accounted for 92% of the variation in live weight ($R^2 = 0.92$), highlighting its diagnostic efficiency (Kunene *et al.*, 2016). Similarly, studies on Jamunapari goats have revealed high genetic correlations between live weight and LBMs such as body length (BL), height at withers (HW), and HG, indicating their utility as effective proxies for selection in weight-based breeding objectives (Kumar *et al.*, 2018; Singh *et al.*, 2020).

Among sheep, chest girth (CG) has consistently exhibited the strongest correlation with body weight across diverse breeds and age cohorts. In a study on Horro sheep in Ethiopia, CG emerged as the most significant and reliable predictor of body weight, irrespective of sex or developmental stage, leading to the formulation of robust regression models for accurate weight estimation (Tibebe *et al.*, 2016). Similarly, investigations in Pelibuey ewes identified CG as the single most predictive morphometric trait for body weight. Moreover, the inclusion of supplementary measurements—such as chest width (CW), body length (BL), and rump width (RW)—in multivariate regression models substantially enhanced the precision of live weight predictions (Torres-Hernández & Domínguez-Viveros, 2018).

Beyond their utility in estimating live body weight, linear body measurements (LBMs) have demonstrated strong predictive associations with carcass attributes. In hair sheep lambs, parameters such as chest girth (CG) and abdominal circumference (AC) have been employed with notable precision to estimate carcass characteristics, yielding coefficient of determination (R^2) values between 0.89 and 0.99 across diverse regression models (Martínez-González *et al.*, 2017). These results reinforce the applied value of LBMs

in livestock production, genetic evaluation, and strategic breeding initiatives. By utilizing easily accessible measurements such as heart girth (HG) and CG, producers and animal scientists are better equipped to make evidence-based selection and management decisions, thereby improving productivity, genetic gain, and overall operational efficiency in livestock systems (Zambrano-Varón *et al.*, 2021).

3.5. Application of Linear Body Measurements in Genetic Improvement Programs for Livestock and Poultry in Sub-Saharan Africa

Linear body measurements (LBMs) have emerged as indispensable instruments in the formulation of genetic improvement strategies, particularly within the context of resource-constrained agricultural systems prevalent across Sub-Saharan Africa (SSA). As practical morphometric indicators, LBMs offer a cost-effective and dependable means of supporting phenotypic selection, especially in settings where access to conventional weighing apparatus and comprehensive genetic evaluation infrastructure remains severely limited (Yakubu *et al.*, 2021).

3.5.1. Phenotypic Selection in Low-Resource Settings

In smallholder and traditional livestock systems, the lack of weighing scales constrains routine performance evaluation and impedes informed decision-making. Linear body measurements (LBMs)—such as heart girth, body length, and height at withers—have shown strong correlations with live body weight and other economically relevant traits in cattle, goats, and sheep (Matsenjwa *et al.*, 2023; Asresie *et al.*, 2021). These traits serve as practical proxies for body weight, enabling farmers and animal health practitioners to assess growth potential and structural soundness in the absence of sophisticated tools.

In resource-limited settings, phenotypic selection remains a cornerstone of genetic improvement, as advanced genomic tools are typically inaccessible. Observable traits—such as body size, coat color, reproductive performance, and disease resistance—serve as reliable indicators of genetic potential. Despite its limitations, phenotypic selection offers a cost-effective and context-appropriate approach to improving productivity and resilience in smallholder and pastoral systems (Yakubu, 2020; Gwaze *et al.*, 2021; Alemu *et al.*, 2022; Bett *et al.*, 2023)^[32, 10, 15].

However, phenotypic selection faces several inherent challenges that limit its precision and sustainability. Key constraints include the low heritability of many economically important traits (e.g., fertility, growth rate, disease resistance), environmental variability, poor record-keeping, limited technical expertise, and the absence of structured breeding programs. These factors make it difficult to distinguish genetic merit from environmental influences based solely on phenotypic observations (Yakubu, 2020; Alemu *et al.*, 2022)^[10].

To improve selection accuracy, on-farm performance testing and statistical adjustment for environmental effects can be adopted. Strategies such as group-based management and uniform feeding regimes help reduce environmental noise and improve trait comparability (Bett *et al.*, 2023)^[15]. Additionally, accurate data collection is critically often lacking—due to illiteracy, low awareness, and absence of incentives among farmers (Gwaze *et al.*, 2021)^[32]. Community-based recording systems, including mobile

applications and participatory tools, have shown promise in addressing these gaps. Simple pictorial or mobile-based tools can help farmers record basic performance metrics effectively (Tesfaye *et al.*, 2021).

A further limitation is the lack of clearly defined and community-driven breeding goals. In many cases, selection decisions are ad hoc, influenced more by socio-cultural preferences than by productivity or resilience considerations (Wollny, 2020). Engaging communities through participatory rural appraisals ensures that breeding objectives reflect both local priorities and long-term sustainability (Bett *et al.*, 2023)^[15].

Finally, most smallholder systems suffer from limited access to technical support, including animal geneticists, veterinarians, and extension officers. Capacity-building initiatives—such as farmer field schools, collaborations with research institutions, and train-the-trainer programs—have demonstrated potential in bridging these knowledge gaps (Alemu *et al.*, 2022)^[10]. Strengthening institutional support and farmer education is essential to sustain genetic improvement efforts in low-input systems.

3.5.2. Heritability and Trait Correlation

Numerous linear body measurements demonstrate moderate to high heritability, making them useful proxy traits in selection programs, especially in resource-constrained environments where direct measurement of economically significant traits is challenging. Heritability estimates for traits like chest girth, body length, and withers height in native small ruminants generally fall between 0.3 and 0.5, reflecting considerable additive genetic variance that can be harnessed through phenotypic selection (Tadesse *et al.*, 2022; Dossa *et al.*, 2020; Adebayo *et al.*, 2021)^[4]. These linear traits are not only straightforward to measure on farms using simple tools such as measuring tapes but are also less influenced by short-term environmental changes, increasing their dependability in field conditions.

Notably, linear traits exhibit positive and significant genetic correlations with growth rate, body weight, reproductive efficiency, and meat yield, making them effective indirect selection criteria in breeding programs aimed at enhancing productivity and adaptation. For instance, chest girth is a strong predictor of live body weight and metabolic efficiency, while body length correlates with skeletal development and carcass frame size (Bett *et al.*, 2023)^[15]. These relationships support the inclusion of linear body measurements in multi-trait selection indices, which can enhance multiple economically important traits simultaneously without the need for expensive performance testing infrastructure (Adebayo *et al.*, 2021; Dossa *et al.*, 2020; Tadesse *et al.*, 2022)^[4]. Additionally, the use of linear traits aligns well with community-based breeding programs (CBBPs), where practicality, farmer involvement, and ease of measurement are crucial for success (Haile *et al.*, 2019; Bett *et al.*, 2023)^[15]. By relying on traits that are easily observed and measured under field conditions, breeding programs can achieve genetic improvement goals in a participatory and cost-effective manner, even in low-resource settings.

Training farmers and local technicians to regularly measure and record these traits facilitates on-farm selection, accelerates genetic progress, and aids in developing locally adapted, resilient animal populations (Haile *et al.*, 2019; Alemu *et al.*, 2022)^[10]. Incorporating linear measurements into breeding strategies thus provides a scalable and context-

appropriate approach for genetic improvement within breeds in smallholder systems across Sub-Saharan Africa.

3.5.3. Breed Characterization and Genetic Resource Management

Breed characterization is the systematic process of identifying, describing, and documenting the phenotypic, genetic, and performance traits of animal genetic resources (AnGR), particularly indigenous breeds. It includes both phenotypic characterization—encompassing physical traits, production contexts, and adaptive features—and molecular characterization, which evaluates genetic diversity through DNA markers (FAO, 2015; Groeneveld *et al.*, 2016). This foundational knowledge is critical for understanding breed potential, ecological adaptability, and conservation status, especially in developing regions where indigenous livestock play a pivotal role in food security, cultural heritage, and climate resilience.

In regions with limited access to genomic tools, morphometric profiling using linear body measurements (LBMs) provides a practical, cost-effective method for breed identification and classification (Yakubu *et al.*, 2021; Ojango *et al.*, 2022). LBMs—such as body length, chest girth, height at withers, ear length, and rump width—are observable and quantifiable descriptors that reflect an animal's external morphology. These measurements capture phenotypic variation that mirrors both genetic differentiation and environmental adaptation among populations.

Many indigenous breeds in smallholder and low-input systems remain poorly characterized, increasing the risk of genetic erosion and loss of traits like disease resistance, feed efficiency, and heat tolerance (Mwacharo *et al.*, 2020). In such contexts, LBMs offer an accessible entry point for phenotypic characterization, enabling within- and between-population comparisons. These profiles support the identification of genetically distinct populations, validate farmers' indigenous classification systems, and inform targeted in situ conservation strategies (Yakubu, 2020; Dossa *et al.*, 2020).

Moreover, LBMs play a central role in the design and implementation of community-based breeding programs (CBBPs). Their field applicability allows farmers to participate directly in selecting breeding stock, thereby enhancing local ownership, building capacity, and supporting data-driven decision-making (Haile *et al.*, 2019; Bett *et al.*, 2023) ^[15]. When integrated with multivariate statistical techniques—such as principal component analysis and cluster analysis—LBMs can effectively distinguish local ecotypes and reveal subtle morphological differences indicative of genetic diversity (Salako *et al.*, 2023).

Beyond breed identification, morphometric characterization supports sustainable utilization by establishing phenotypic baselines, developing selection indices, and identifying animals with desirable conformation traits. These applications contribute to both genetic improvement and the conservation of locally adapted genotypes, reinforcing the sustainable management of animal genetic resources in Sub-Saharan Africa and other low-resource regions.

Complementing breed characterization, genetic resource management involves the conservation, sustainable use, and development of AnGR. This includes in situ conservation (maintaining animals within their production environments), ex situ strategies (e.g., cryopreservation of semen or embryos), and breeding programs that balance genetic

diversity with productivity goals (Mwacharo *et al.*, 2020; FAO, 2021). These approaches ensure the long-term availability of genetic resources, enabling adaptive responses to challenges such as climate change, disease emergence, and evolving market demands.

Ultimately, effective breed characterization and genetic resource management are foundational to evidence-based livestock development. They guide the design of CBBPs, help identify at-risk breeds, and inform policy decisions aimed at safeguarding indigenous genetic diversity. In resource-constrained settings, where local breeds are often underutilized and under-documented, these efforts are vital for harnessing untapped genetic potential and securing future livestock resilience (Yakubu, 2020; Ojango *et al.*, 2022).

3.5.4. Role of Standardized LBMs in Genomic-Enhanced Breeding Strategies in SSA

Standardized linear body measurements (LBMs) play a pivotal role in the modernization of livestock genetic improvement programs, especially as genomic resources become increasingly accessible in sub-Saharan Africa (SSA). While LBMs have traditionally been used for phenotypic selection due to their moderate-to-high heritability and ease of measurement, their true potential is unlocked when combined with genomic information, such as single nucleotide polymorphism (SNP) genotyping and whole-genome sequencing (Chagunda *et al.*, 2023).

By integrating phenotypic data from LBMs with molecular marker data, breeding programs can improve the accuracy of estimated breeding values (EBVs) for traits that are otherwise difficult or expensive to measure directly, such as disease resistance, thermotolerance, fertility, and feed efficiency (Van Marle-Köster *et al.*, 2020). This integration enables the application of genomic selection, which can significantly shorten generation intervals, accelerate genetic gains, and improve selection intensity, even in smallholder and pastoral production systems.

For example, genomic prediction models trained on LBMs and productivity traits allow breeders to select animals with superior genetic merit earlier in life, thereby increasing the efficiency of both natural mating and artificial insemination (AI) programs. Moreover, LBMs provide a low-cost phenotypic baseline to validate genomic predictions and ensure trait relevance under local environmental conditions (Kim *et al.*, 2021; Ojango *et al.*, 2022). This is particularly important in indigenous livestock populations, where adaptation to local stressors is a key breeding objective.

In community-based breeding programs (CBBPs), standardized LBM protocols facilitate data harmonization across locations and time periods, enabling multi-site genomic evaluations (Mrode *et al.*, 2020). They also enhance farmer engagement, since body measurements are observable and actionable, making them an effective bridge between traditional selection knowledge and modern genomic technologies. Ultimately, the synergy between LBMs and genomic data paves the way for precision breeding in SSA—one that is both scientifically robust and contextually grounded, thereby improving food security, climate resilience, and rural livelihoods.

3.6. Application of Linear Body Measurements (LBMs) in Indigenous Poultry Improvement

Indigenous poultry, particularly village chickens, are integral to the livelihoods, nutrition, and cultural traditions of rural

households across Sub-Saharan Africa. These birds thrive in low-input systems and contribute significantly to food security. However, efforts to improve their genetic potential have been limited by inadequate infrastructure, poor data recording systems, and the absence of organized breeding programs.

In such resource-constrained environments, linear body measurements (LBMs) provide a feasible and economical alternative for assessing both phenotypic traits and underlying genetic variation. Traits such as body length, shank length, keel length, chest girth, and wing span are relatively easy to measure in the field and do not require sophisticated equipment. These measurements have demonstrated strong correlations with key performance indicators such as live weight, growth rate, and reproductive output. Given their moderate to high heritability, LBMs serve as reliable selection indicators, especially in community-based breeding programs where formal performance testing is often not feasible (Yakubu *et al.*, 2021; Adeleke *et al.*, 2022).

LBMs also support the classification and characterization of local chicken ecotypes, enabling the identification of genetic diversity within and between populations. Such diversity reflects long-term adaptation to varied agro-ecological zones and traditional husbandry practices (Mtileni *et al.*, 2020; Gondwe & Wollny, 2021). Standardizing the use of LBMs across breeding programs enhances within-population selection and provides a foundation for broader genetic evaluations, thereby contributing to the design of sustainable and targeted improvement strategies.

As the use of genomic technologies expands, LBMs will remain a vital source of phenotypic data that can be integrated into genetic evaluations. When combined with molecular tools, these measurements enhance the accuracy of estimated breeding values (EBVs) and facilitate the implementation of marker-assisted or genomic selection, allowing for more efficient breeding of resilient and productive indigenous poultry.

In practical breeding interventions across countries such as Uganda, Nigeria, and Ethiopia, LBMs—particularly shank, keel, and body length—are widely employed to identify superior individuals within dual-purpose genotypes like Sasso and Kuroiler. These traits support selection for both meat and egg production under varying environmental conditions (Wondmeneh *et al.*, 2020; Adeleke *et al.*, 2021). By offering a scalable, low-cost, and data-rich approach, LBMs help bridge the gap between traditional and modern breeding efforts.

With the increasing adoption of mobile data collection tools and digital platforms, the utility of LBMs is expected to grow. Their integration into national and regional breeding frameworks can significantly enhance the precision and impact of genetic improvement programs, not only for poultry but also for broader livestock development in Sub-Saharan Africa.

4. Conclusion

Linear body measurements (LBMs) have emerged as a vital tool in livestock genetic improvement, particularly in resource-constrained settings. Recent studies reveal that heritability estimates for these traits vary considerably across species, breeds, and specific body dimensions, typically falling within the low to moderate range. This variability highlights the need for species- and trait-specific strategies

when designing selection and breeding programs. Despite the influence of environmental factors, several LBMs show moderate to high heritability and strong genetic and phenotypic correlations with economically important traits such as body weight, growth rate, and reproductive performance. This makes LBMs a practical and cost-effective proxy for more complex and resource-intensive selection criteria, especially in regions where molecular tools remain inaccessible.

The inclusion of LBMs in breeding indices offers a scalable opportunity for immediate genetic gains. In rabbits, for instance, consistent positive correlations between LBMs and growth traits affirm their utility in enhancing overall productivity through informed selection. However, the accuracy of genetic evaluations using LBMs is heavily influenced by non-genetic factors, such as age, sex, housing system, season, and, critically, nutrition. Age-specific changes in morphometric traits necessitate careful interpretation to avoid confounding effects, particularly in indigenous production systems where age records are often incomplete or absent. Similarly, the significant impact of sex on body dimensions—largely due to hormonal differences—must be accounted for in evaluations to ensure the reliability of genetic parameter estimates.

Nutritional status plays a pivotal role in shaping phenotypic expression and directly affects the development of skeletal and muscular structures. Given that feed quality and availability often fluctuate in developing regions such as sub-Saharan Africa, incorporating nutritional considerations into selection strategies is essential for achieving consistent and meaningful genetic improvement. Addressing these environmental influences enhances the precision of selection, promotes animal adaptability, and supports sustainable productivity under diverse agro-ecological conditions.

In conclusion, while LBMs alone may not capture the full genetic potential of livestock, their integration into selection programs offers a robust, accessible, and efficient approach to improving animal performance. Policymakers, researchers, and development agencies should prioritize the standardization and dissemination of LBM measurement protocols and invest in capacity-building initiatives to facilitate their adoption. Doing so will not only enhance genetic gains but also support resilient, context-appropriate livestock improvement programs tailored to the unique challenges of developing regions.

Highlights

- LBMs are robust, low-cost indicators for genetic selection.
- Strong genetic correlations exist between LBMs and performance traits.
- Non-genetic factors must be controlled for accurate interpretation.
- LBMs support both phenotypic selection and genomic integration.
- Institutional investment is key to mainstreaming LBMs in breeding strategies.

References

1. Abebe AM, Tadesse M, Worku S. Effects of feeding practices on growth and morphometric traits of indigenous goats in dryland areas of Ethiopia. *Trop Anim Health Prod.* 2023;55(1):12. doi:10.1007/s11250-023-

- 03655-8
2. Abegaz S, *et al.* Genetic parameters and breeding strategies for small ruminants in Africa. *Afr J Agric Res.* 2020;15(9):1200–1210.
 3. Abegaz S, Tadesse M, Haile A. Morphometric traits and sexual dimorphism in indigenous sheep populations of Ethiopia. *Trop Anim Health Prod.* 2022;54(3):140. doi:10.1007/s11250-022-03161-1
 4. Adebayo OO, Akinyemi MO, Yakubu A. Heritability and genetic correlations of linear body measurements and body weight in West African Dwarf goats. *Trop Anim Health Prod.* 2021;53:485. doi:10.1007/s11250-021-02642-7
 5. Ajayi FO, Olumide MD, Alabi JO. Age-related morphometric growth patterns in indigenous chickens under improved management. *Niger J Anim Prod.* 2021;48(2):91–99.
 6. Akin M. Genetic parameters for linear type traits and their relationship with milk yield in Holstein cows in Turkey. *Turk J Vet Anim Sci.* 2016;40(1):32–38. doi:10.3906/vet-1503-47
 7. Akinola LAF, Egena SSA, Momoh OM. Effects of dietary protein levels on growth performance and morphometric traits of local chickens in Nigeria. *J Anim Prod Res.* 2021;33(2):89–97.
 8. Alabi OJ, Peters SO, Imumorin IG, Adebambo OA, Ikeobi CON. Genetic evaluation of linear body measurements and reproductive traits in indigenous goat populations. *Trop Anim Health Prod.* 2019;51(7):1865–1872. doi:10.1007/s11250-019-01918-2
 9. Alemayehu K, Getachew T, Haile A. Nutritional effect on growth performance and linear body measurements in Ethiopian indigenous goats under different feeding regimes. *Trop Anim Health Prod.* 2021;53(2):196. doi:10.1007/s11250-021-02586-z
 10. Alemu AM, Hassen HH, Rege JEO. Phenotypic and genetic evaluation of indigenous livestock breeds under low-input systems in Sub-Saharan Africa: opportunities for selection. *Trop Anim Health Prod.* 2022;54(2):45. doi:10.1007/s11250-021-03029-5
 11. Ali A, Hassan R, Younas M. Morphometric traits and sexual dimorphism in indigenous cattle breeds of Pakistan. *Trop Anim Health Prod.* 2021;53(1):41. doi:10.1007/s11250-020-02462-2
 12. Bayram B, Yilmaz O, Ertuğrul M. Assessment of age-related changes in morphometric traits in native Turkish cattle breeds. *Vet J Ankara Univ.* 2021;68(4):413–420. doi:10.33988/auvfd.804565
 13. Bello N, Yakubu A, Ari MM. Morphological characterization and principal component analysis of Uda sheep in Nigeria. *Livest Res Rural Dev.* 2020;32(5). Available from: <http://www.lrrd.org/lrrd32/5/bell32074.html>
 14. Berry DP, Buckley F, Dillon P, Evans RD, Rath M, Veerkamp RF. Genetic relationships among body condition score, body weight, milk yield, and fertility in dairy cows. *J Dairy Sci.* 2004;86(6):2193–2204. doi:10.3168/jds.S0022-0302(03)73809-0
 15. Bett RC, Kosgey IS, Kahi AK, Van Arendonk JAM. Strengthening livestock genetic improvement programs in Africa through participatory approaches. *Front Genet.* 2023;14:1145290. doi:10.3389/fgene.2023.1145290
 16. Bimrew A, *et al.* Evaluation of linear body measurements as selection criteria in indigenous sheep of Ethiopia. *Trop Anim Health Prod.* 2022;54(1):6.
 17. Blackmore DW, Welch RM, Bell AK. Heritability of body weight in dairy cattle. *J Dairy Sci.* 1958;41(12):1770–1776. doi:10.3168/jds.S0022-0302(58)91188-0
 18. Bramer WM, Rethlefsen ML, Kleijnen J, Franco OH. Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study. *Syst Rev.* 2018;6:245. doi:10.1186/s13643-017-0644-y
 19. Carneiro RLS, Verneque RS, Balieiro JCC, Silva MVGB, Penna VM. Genetic parameters for body weight and milk yield traits in Gyr dairy cattle. *Trop Anim Health Prod.* 2016;48:1045–1050. doi:10.1007/s11250-016-1045-2
 20. CASP. Critical Appraisal Skills Programme (CASP) checklists. 2023. Available from: <https://casp-uk.net/casp-tools-checklists/>
 21. Chala M, Alemu T, Worku S. Growth pattern and morphometric characterization of indigenous cattle under extensive management systems. *Ethiop J Anim Prod.* 2020;20(1):32–41.
 22. Deribe B, Melesse A. Growth performance and morphometric traits of indigenous chicken ecotypes as influenced by age and sex. *Poult Sci.* 2023;102(2):102312. doi:10.1016/j.psj.2022.102312
 23. Dossa LH, *et al.* Morphometric variation and its implications for goat breeding in West Africa. *Small Rumin Res.* 2021;199:106343.
 24. Dossa LH, Sangaré M, Buerkert A, Schlecht E. Genetic parameters of body measurements and their relationship with body weight in Djallonké sheep. *Small Rumin Res.* 2020;184:106047. doi:10.1016/j.smallrumres.2020.106047
 25. Dossa LH, Vanvanhossou FUS, Youssao AKI. Phenotypic differentiation and sexual dimorphism in West African Dwarf and Djallonké sheep. *Small Rumin Res.* 2021;203:106519. doi:10.1016/j.smallrumres.2021.106519
 26. Duguma G, Yohannes T, Wondimu T. Genetic parameters of scrotal circumference and growth traits in Ethiopian sheep breeds. *Small Rumin Res.* 2021;197:106317. doi:10.1016/j.smallrumres.2021.106317
 27. Ebegebulem VN, Udeh I, Ugwu IS. Evaluation of sexual dimorphism in morphometric traits of indigenous chickens in Southeastern Nigeria. *Livest Res Rural Dev.* 2023;35(2). Available from: <http://www.lrrd.org/lrrd35/2/ebeg35016.html>
 28. Ebiwonjumi TM, Ogundipe RI, Alabi BO. Growth and conformation response of West African Dwarf sheep to nutritional supplementation under semi-intensive system. *Niger J Anim Sci.* 2021;23(2):114–123.
 29. Edeh HO, Ibe SN, Osakwe II. Assessment of sexual dimorphism and morphometric traits of West African Dwarf goats in southeastern Nigeria. *Niger J Anim Prod.* 2020;47(2):67–74. doi:10.51791/njap.v47i2.200
 30. Gernand E, König S, Swalve HH. Genetic parameters for dairy traits and linear conformation traits in Holstein cows. *J Anim Breed Genet.* 2019;136(2):118–128. doi:10.1111/jbg.12369
 31. Gizaw S, *et al.* Phenotypic and genetic characterization of livestock breeds in Sub-Saharan Africa. ILRI Working Paper. 2023.
 32. Gwaze FR, Dzomba EF, Mapiye C. Sustainable

- utilization of indigenous livestock genetic resources in low-input production systems in Africa. *Anim Genet Resour.* 2021;69:15–25. doi:10.1017/S207863362100003X
33. Haile A, Melesse A, Getachew T. Influence of production system and seasonal variability on growth and conformation traits of Ethiopian indigenous sheep. *Trop Anim Health Prod.* 2020;52(4):1781–1790. doi:10.1007/s11250-020-02249-6
 34. Haile A, Wurzinger M, Mueller J, *et al.* Guidelines for setting up community-based sheep breeding programs in Ethiopia. *Livest Res Rural Dev.* 2019;31(6):Article 98. Available from: <http://www.lrrd.org/lrrd31/6/haile31098.html>
 35. Hailemariam T, Tolemariam T, Mekasha Y. Impact of nutritional status on morphometric traits and body weight of indigenous cattle in southern Ethiopia. *Ethiop J Anim Prod.* 2020;20(2):45–54.
 36. Higgins JPT, Thomas J, Chandler J, *et al.* Cochrane handbook for systematic reviews of interventions. Version 6.3. Cochrane; 2022. Available from: <https://training.cochrane.org/handbook>
 37. Ibrahim AA, Musa AM, Bako AO. Morphological characterization and sexual dimorphism in Uda sheep under traditional management in Nigeria. *J Anim Sci Vet Med.* 2023;8(1):11–18. doi:10.31248/JASVM2023.358
 38. Ibrahim H, Abdussamad AM, Adeoye A. Effect of age on growth traits and morphometric development in West African Dwarf goats. *Niger J Anim Prod.* 2023;50(1):75–83. doi:10.51791/njap.v50i1.500

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