RESEARCH ARTICLE

Phenotypic Characteristics and Factors Associated with Assaf Lamb Body Weight and Morphology

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Abstract

The phenotypic characteristics of animals are result of the interaction of genetic and non-genetic factors that act simultaneously, and it is difficult to determine the degree of influence of each of them.

The goal of this study was to describe Assaf lamb morphology and its relationship with body weight (BW) at various ages. BWs and phenotypical characteristics measurements were taken on 392 lambs, 204 lambs at birth (±3 days of birth), 87 lambs at weaning (around 60 days), and 101 lambs at marketing age (around 120 days). The measurements were withers height (WH), body length (BL), chest girth (CG), chest depth (CD), head length (HL), head width (HW), rump length (RL), RW (RW), shoulder width (SW), shin circumference (SC), foreleg height (FLH), rump height (RH) and rear leg height (RLH).

Month of birth (MO) affected ($P<0.001$) BW and all morphological characteristics except CD and RW at birth. At weaning, BW, HL, CG, RL, CD, SW, and RW were affected ($P<0.001$) by MO. Sex of the lamb, birth type, and dam age also affected ($P<0.001$) different morphological characteristics. Furthermore, BW was positively correlated with different morphological characteristics at different ages. Meanwhile, equations were developed to predict BW at birth, weaning, and marketing based on various morphological characteristics while taking high into account.

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Introduction

In many livestock species, conformation traits have been included in the genetic evaluation procedures and selection programs can incorporate estimated breeding values for these traits. At the same time, body weight increase is one of the essential goals in sheep production improvement programs, which requires adequate knowledge of correlated traits that can be considered when selection is to be applied[1]. Morphological and productive aspects in a population evolve over time as a result of natural and artificial selection, mutation, migration, and genetic drift. Biometrical measurements have been used to evaluate the characteristics of the animals that may vary due to the influence of breed evolution, environment and nutrition[2].

The morphological characteristics are the most important traits describing the meat yield of farm animals beside body weight (BW) (at birth, weaning, and marketing), growth rate, reproductive efficiency, and carcass characteristics[3]. As a result, morphological characteristics are an important tool for describing breed standards and their development abilities[4][5]. Therefore, describing the breed's morphological characteristics is an essential step before developing strategies for a breeding program aiming at improving the breed productivity[6]. It is worth mentioning that morphological characteristics differ according to many factors such as breed, age, sex, type of birth, and month of birth[7][8].

Body dimensions or linear measurements have been used as indicators of body size and weight, and live body weight can be predicted from body measurements. The phenotype of an animal for size and conformation is the result of the genetic potential and the influence of environment as well as maternal effects. Measurements of body dimensions of animals may be taken at a relatively early age; therefore, the influence of maternal effects on these traits needs to be quantified to formulate optimal breeding programs[9].

Interestingly, sheep have a balanced relationship between BW and morphological characteristics[5]. BW is a very important sheep production characteristic. Knowledge of an animal's BW is necessary for managing decisions regarding, for example, growth, feed requirements, selection, and marketing[10]. In some cases, farmers are often relying on visual assessment to determine the animal's BW due to a lack of weighing scales. BW can be predicted using morphological characteristics such as BL or CG[11][12]. Therefore, several researchers have developed equations to estimate BW from some morphological characteristics[13].

Assaf sheep breed is one of the common dairy breeds in the Middle East region. It is a crossbreed of Awassi and East Friesian breeds, consisting of 5/8 Awassi and 3/8 East Friesian sheep[14][15]. This breed is a dual-purpose breed used for both meat and milk production; but primarily for milk production[16]. Assaf sheep showed higher fertility and milk production than Awassi sheep[17]. In other words, they are distinguished for higher milk productivity and twinning ability compared to Awassi sheep. It became available in Jordan, and many farmers raised Assaf sheep under sedentary (semi-intensive) system to benefit from high milk productivity[17]. In fact, Assaf sheep morphological characteristics and their relationship with BW at different ages were not previously determined in Jordan or worldwide, and only adult Assaf were measured in other countries[8]. To the best of our knowledge, the scientific literature lacks researches on the body morphological characteristics of Assaf lambs.

Therefore, the main objective of this study was to describe BWs and the morphological characteristics of Assaf lambs in Jordan at birth, weaning, and marketing ages and to study the effects of several factors, including sex, type of birth, month of birth, mother's age, and parity, on these characteristics, along with calculating the correlation coefficients among different morphological characteristics and BWs to make the best prediction equations of BWs based on the studied morphological characteristics.

Materials and Methods

Location

This research was carried out during the period from November 2021 to June 2022 at the Ain Jalut farm (a private farm) located in Moubes, Al-Balqa governorate, at 32° 06' 10" N, 35° 52' 09" W, and an altitude of 635m, 20km to the northeast of Amman, the capital city of Jordan. The temperature ranges from 12 to 36 °C, and the average precipitation is 515mm.

Ethical approval

The Research Animal Care and Use Committee gave its approval to the experimental design and procedures.

Animal Management

The planed breeding season of the ewes was extended over the whole year, so that lambing occurred in all months and the ewes to be milked year-round. Similarly, male lambs were fattened after weaning in order to be marketed at marketing weight all year. During the last 4 weeks of pregnancy, each dam was given 300g of alfalfa hay, 500g of straw, and 900g of concentrates. Following lambing, the concentration increased to 1.2kg. The concentrate diet consisted of 80 % barley, 6 % soybean meal, 6 % wheat bran, 1.5 % salt, 1.5 % vitamins and minerals, and 5 % leftover bread. At lambing, lambs were ear-tagged and weighed directly after birth in individual lambing pens. At the age of 20 days, creep feeding was introduced. Creep feed contains 54% crumbed barley, 15 % soybean meal, 20 % alfalfa, 10 % wheat bran, 0.5 % salt, and 0.5 % mineral mixture made up of the creep feed. Gradual weaning was performed at two months of age. After weaning, lambs were given 300–500 g of concentrate per day. The ration was made up of 50 % crumbed barleys and 20 % corn. 16 % soybean meal, 12 % wheat bran and leftover bread, 1.2 % salt, and 0.8 % minerals and vitamins.

Data Collection

The live BW and thirteen linear morphological characteristics were recorded on 392 lambs of different ages (204 at birth, 87 at weaning, and 101 at marketing). The measurements were taken before feeding the lambs. The animal was standing upright and confined in such a way that its head, neck, and barrel were virtually extended in a straight line for the morphological characteristics measurement. In addition, five class characteristics were reported on each lamb, including body color, nose and ear shapes, and the presence of horns and wattles.

The morphological characteristics considered were withers height (WH), body length (BL), chest girth (CG), chest depth (CD), head length (HL), head width (HW), rump length (RL), rump width (RW), rump height (RH), shoulder width (SW), shin circumference (SC), foreleg height (FLH) and rear leg height (RLH) (Al-Tarayrah and Tabbaa, 1999).

Statistical Analysis

Least squares analysis were utilized to study the effects of different environmental factors on BW and morphological characteristics using GLM procedures of the Statistical Analysis System[18]. The following mixed model was used:

$$Y_{ijlkmp} = M + Q_i + R_j + T_l + S_k + U_m + e_{ijlkmp}$$

Where Y_{ijlkmp} is the observed value of the “P” lamb of the “i” month of birth, the type of birth “j”, the “l” dam age, the “k” sex of lambs and “m” age at measurement, M is the overall mean. Q_i is the effect of the “i” month of birth, R_j is the effect of “j” type of birth, T_l is the effect of “l” dam age, S_k is the effect of “k” sex of lambs, U_m is the effect of “m” age at measurement, and e_{ijlkmp} is the random error assumed to be normally and independently distributed with zero mean and homogenous variance. Mean separation was performed using a t-test for the different levels of significant factors affecting BW and morphological characteristics at P < 0.05.

The correlations among BW and morphological characteristics were calculated using the CORR procedure[18] for each age separately. Lastly, prediction equations for BW at each age were performed using stepwise regression analysis using the REG procedure[18]. All morphological characteristics were included in the multiple regression model, which left it to the program to select the best combination of morphological characteristics based on significance.

Results and Discussion

Body Weight morphological characteristics

The means and standard deviations of BW and the morphological characteristics of Assaf lambs at birth, weaning, and marketing are presented in Table 1. Birth weight is an important indicator because it expresses how the lamb was developed during pregnancy; prenatal growth index is considered[10]. Husbandry system influences body measurements, animals’ development can be influenced by management and feeding. Skeletal development seems to be favorable for sheep from transhumance system, hock measures being lower for sheep from sedentary system. The larger body size in sheep from transhumance system is probably due to the positive effects of transhumance, since walking activity and exposure to the sun could promote calcium absorption and bones growth; moreover, shepherds prefer tall animals for grazing[2]. The mean BW at birth was 6.01 kg. This was higher than that reported by other researchers. For example, Rosov and Gootwine[19] reported the mean birth weight of Assaf lambs to be 4.5 kg. Similar values were reported by Ocak and Cankaya[20] for Assaf lambs' birth weight to be 4.27 kg. However, comparing with the Awassi breed. Sireli et al.[21] reported the mean value to be 4.81 kg. In another study, Suliman et al.[22] found the birth weight to be 4.1 kg for Awassi lambs. On the other hand, Abdullah and Tabbaa[23] reported the birth weight of Awassi-Chios crossbreed to be 4.2 kg.

The means for morphological characteristics at birth were also reported in Table 1. To the best of our knowledge, there is no prior research on the body morphological characteristics of Assaf lambs reported by other researchers. Awassi lambs had similar values for the measurements of morphological characteristics reported in this study[23].

At weaning age, Assaf lambs had a value of 20.40 kg for the BW mean (Table 3). Ocak and Cankaya[20] reported the average BW of Assaf lambs at 60 days of age to be 12.64 kg, while Rosov and Gootwine[19] reported a higher value at the same age for Assaf lambs: 14.7 kg. Comparing with Awassi lambs, Suliman et al.[22] reported the average BW at 60 days of age to be 21.1 kg, and a similar value (19.15 kg) was reported by Al-Tarayrah and Tabbaa[24]. Panayotov et al.[25] found the average weaning weight for the Lacaune breed to be 15.93 kg.

The morphological characteristics of Assaf lambs that are presented in Table 3. The highest growth rate from birth to weaning of this morphological characteristic was also for BL. Comparing with Awassi lambs, Al-Tarayrah and Tabbaa[24] reported values for CG, BL, SW, RW, WH, and RH to be similar to Assaf lambs at 60 days of age. In another study, Kecici et al.[26] reported values for the wither’s heights, RHs, BL, CD and chest width for Kivircik lambs, which were at weaning and were less than those of Assaf lambs. The BW and morphological characteristics in this study were higher than those reported by other researchers on the Awassi and Lacaune sheep breeds[24][25]. Body weight is a very important characteristic in animal husbandry as a selection criterion and measure of economic profit. Live body weight might be affected by management, environment and feeding conditions[27]. A significant effect of litter size on body length and hearth girth was also observed in Finnish sheep, Suffolk and synthetic rams at 6 and 8 months of age, so it may be considered an important source of variation in body measurements[2].

Assaf lambs' average marketing weight was 32.08kg. Despite the fact that the marketing age of Awassi was at 150 days, as reported by Al-Tarayrah and

Tabbaa[24], it was 25.27 kg, and in another study, the average weight of Thalli lambs at marketing age was 18.95 kg[28]. This shows that the Assaf growth rate for marketing was much higher than that of Awassi or Thalli lambs.

The means of morphological characteristics are presented in Table 3. The highest growth rate from weaning to marketing of this morphological characteristic was also for CG. Al-Tarayrah and Tabbaa[24] found that the average morphological characteristics of CG, BL, SW, RW, WH, and RH were closer to Assaf lambs at 150 days of age. Kecici et al.[26] reported lower values for WHs, RHs, BL, chest depth, and chest width at marketing age for Kivircik lambs than those of Assaf lambs.

The percentages of descriptive characteristics of Assaf lamb such as body color patterns—white and a mixture of black and white showed the white color has a higher percentage (74.55 %) compared to the black and white color (25.45 %). The shape of the nose varied between slightly convex (46.41 %) and straight nose being more common (53.59%). As for the horns, presence of horns (63.77 %) was more common than the absence of horns. There was one size for the ears in all Assaf lambs which was medium (100 %) in length and width. However, wattles were not found in all Assaf lambs at birth, weaning, or marketing ages.

Month of birth

The month of birth significantly (P<0.001) affected BW and most morphological characteristics (Figure 1), however, it had no effect on CD and RW at birth age. Similarly, Al-Tarayrah and Tabbaa[24], Mousa et al.[29], Sulaiman et al. (2014), and Petrovic et al.[30] reported the effect of month on the birth weight of Assaf, Farafra, Awassi, Piro X Wurttemberg, and Fjenica X Wurttemberg lambs. Though, Yilmaz et al.[6] found that the month of birth has no effect on birth weight. Also, Al-Tarayrah and Tabbaa[24] found that the month of birth affected some morphological characteristics, such as the BL and CG of Awassi lambs.

The significant effect of month of birth on some morphological traits have been reported for Suffolk, Finnish sheep, and Awassi breeds; contrary to the findings reported that the effect of month of birth on body measures of Bergamasca sheep had no statistical significance[2].

At weaning age, RL, CD, SW (P<0.001), BW, CG, RW (P<0.01) and HL (P<0.05) have been significantly affected by the month of birth and did not affect HL, shin circumference, BL, WH, FLH, RH and RLH (Figures 2A). Similarly, Yilmaz et al.[6] reported that the month of birth affected BW at weaning age for Norduz lambs, and Norouzian[31] found that the season of birth had an effect on BW, BL, CG, and WH in Balouchi lambs at weaning age. Growth rate was affected by the birth season of Ouled Djellal lambs up to weaning age[32]. In addition, Al-Tarayrah and Tabbaa[24] reported that month of birth not only affected BW at weaning age of 60 days but also several morphological characteristics such as SW, hip width, WH and hip height in Awassi lambs. At marketing age, the month of birth has significantly affected BL, SW rump weather (P<0.001), BW, HW, RLH (P<0.01), CG, SC and RL (P<0.05) (Figures 2B). Month of birth, however, did not affect HL, WH, FLH, RW, RLH. Norouzian[31] and Kuchtik and Dobes[33] reported that the month of birth influences the BW of Balouchi and crossbred Wallachian and East Friesian lambs at marketing age. In addition, Yilmaz et al.[6] reported that season of birth has an effect on Norduz lambs' BW at 180 days of age. In another study, the month of birth did not affect BW or any of the morphological characteristics of Awassi lambs at 150 days of age[24]. Earlier findings reported that winter born lambs were heavier at birth and weaning than both fall and summer born lambs, while others reported spring lambs to be heavier at birth than fall-born lambs. Contrary, spring-born lambs were heavier at birth than winter-born lambs. The seasonal differences in birth weight in the current study may have been partly due to differences in ambient temperature and maternal pre-natal effects during gestation[6].

The reason why winter-born lambs had higher growth rate compared with spring-born lambs could in part be attributed to extra supplement provided in barn. In addition, post-weaning of spring-born lambs corresponded to time when pasture quality was lacking and lambs received no additional supplement[6].

Type of birth

Type of birth significantly affected CG, BL, WH (P<0.01), weight, SW, FLH and RLH (P<0.05) but had no effect on HW, HL, SC, RL, CD, RW and RH at birth (Table 2). As expected, single born lambs were heavier at birth than twins or triplets; they were 6.43, 6.24 and 5.64kg, respectively. Singles also had larger morphological characteristics than twins. Similarly, in other studies, the type of birth affected the birth weight of Romney Marsh, Mehran, Blame, and Farafra lambs[34][35][36][29].

Among the factors that influence lamb birth weight, type of birth, is considered the main factor of variation in lamb growth (Ajoy et al., 2008). The birth weight advantage of single born lambs over the multiple born lambs may be due to competition for nutrient and uterine space[36]. Many researchers also reported that the type of birth influenced several morphological characteristics, including RHs, CD, chest width (BL, SW), hip width (WH), and hip height (CG)[24][26]. The effect of singleton or twin status on body length was significant before weaning, this effect did not remain significant after weaning (Sulaiman et al., 2014).

Single born lambs were heavier at weaning than multiples; they were 21.80 and 19.36 kg, respectively. Similarly, singles had a higher weaning weight and average daily gain than twins because of the competition between twins to feed on their mother's milk[6][30]. Weaning weight is strongly affected by the maternal environment, and thus the good maternal ability that characterizes some breeds exerts a greater influence on this productive parameter than genotype[37].

At weaning age, type of birth had a significant effect on WH (P<0.001), HL, RH, RLH (P<0.01), BW, and CD (P<0.05) and had no effect on HW, CG, SC, BL, RL, SW, RW and FLH (Table 3).

Also, singles were found to be larger in all morphologic characteristics than multiples. These results agreed with the findings of Al-Tarayrah and Tabbaa[24] who found that the type of birth affected BW, BL, SW, hip width, WH, hip height, and CG for Awassi lambs. Other studies, however, found no effect of birth type on lamb BW at weaning[38][39].

At marketing age, the type of birth was significantly affected BW, RH and RLH (P<0.05) and had no effect on other morphologic characteristics in this study (Table 4). Single born lambs were heavier at birth than multiples; they were 33.09 and 30.74 kg, respectively. Similarly, Momoh et al.[36] reported that type of birth influenced BW and average daily gain at 6 months of age for Balami and Uda lambs. However, Al-Tarayrah and Tabbaa[24] reported that the type of birth affected more morphologic characteristics than our study. In their study, type of birth had an effect on BW, BL, SW, hip width, WH, hip height, and CG of Awassi lambs at 150 days of age. Also, Kecici et al.[26] found more effects of type of birth on BW, and morphologic characteristics such as WHs, RHs, BL, CD and chest width at the marketing age for Kivircik lambs.

Sex of lambs

The sex of the lambs affected birth weight, where males were heavier than females[34][6][15][37]. At birth, the sex of lambs significantly (P<0.05) affected only SC and did not affect BW or any other morphological characteristics (Table 2). Similarly, Kecici et al.[26] reported that the sex of Kivircik lambs did not affect withers heights, RHs, BL, chest width, or chest circumference. However, Al-Tarayrah and Tabbaa[24] reported that the sex of lambs had an effect on birth weight, CG, WH, hip height, withers width, and hip depth in Awassi lambs. In addition, sex was found to significantly affect birth weight and CD. In general, lamb sex significantly affected all body measurements at all age points until 12 months of age, with male lambs being larger than females (Sulaiman et al. 2014). This may be a result of the presence of the Y chromosome and higher androgen levels in males. Increased differences between male and female lambs after weaning may be the result of testosterone effects on growth.

Several studies have indicated that male lambs are heavier than females at birth indicate that the presence of a Y-chromosome and the products of SRY gene activation explain the effects of sex on fetal growth maternal environment (maternal body composition prior to pregnancy and maternal nutrition during late gestation) has the largest influence on birth weight[37]. [40] revealed that weight at birth is influenced by lamb sex and significant statistical differences were observed between sexes separately in single births, where males were heavier than females. Between males and females of births twins, there were no significant differences

Momoh et al.[36] suggested that sex effect on BW was ascribed to hormonal action. Estrogen hormone has a limited effect on the growth of long bones in females. As the lambs grow, the males probably beginning to secret androgenic substances earlier grow and develop faster than the female. That could be one of the reasons in which females have smaller body and lighter weight against males.

The sexes have a significant effect on HW (P<0.01), SC, CD, whether height, RH, and RLH (P<0.05) at weaning age, but no effect on other characteristics (Table 3). Similarly, in Awassi lambs sex affected birth weight, BL, SW, hip width, WH, hip height, and CG at 60 days of age[24]. At weaning, Petrovic et al.[30] reported that sex had an effect on the BW of Pirot X Wurttemberg and Sjenica X Wurttemberg crossbred lambs while Kecici et al.[26] found that sex did not affect WHs, RHs, BL, chest width and chest circumference of Kivircik lambs.

At marketing age, sex of lambs significantly affected SC (P<0.001), HW, HL, BL, RL, RL and FLH (P<0.01) and did not affect BW, CG, CD, SW, RW, WH, RH and RLH (Table 4). Other researchers reported that sex significantly affected marketing weight, BL, SW, hip width, WH, hip height, RHs, BL, CD and CG in Awassi and Kivircik lambs[24][26]. Momoh et al.[36] reported that the sex of lambs had effects on all growth traits from birth to yearling weight in Balami and Uda lambs. Also, Al-Azzawi et al.[41] reported that sex affected BL, hip height, WH and hip width, while CG and SW were not affected by sex at 6 months of age in Awassi lambs.

[42] reported that all body measurements were similar between male and female for Santa Ines lambs in the milk teeth stage. On the contrary, other studies

showed that male lambs consistently had higher body measurements (CG, CW, BL, and WH) after weaning (75d age).

As explained by[42], differences in sexual chromosomes, physiological characteristics, and the endocrinal system (type and measure of hormone secretion, especially sexual hormones), explain why males are heavier than females. Other studies indicate that the sexual selection hypothesis is considered a general explanation for sexual size dimorphism, whereby intense sexual selection drives the evolution of body size in the selected sex, usually males, with weaker correlated selection on body size in the other sex[37].

The sex ratio was 52.4 % male and 47.6 % female. There was no effect of the sex of the lambs on body color or nose shape, while there was a significant (P < 0.05) effect on the presence of horns, as males (69.14 %) have a greater percentage of horned lambs than females (57.86 %).

Damage

At birth, dam age significantly (P<0.05) affected HL and WH (Figures 3), however, it did not affect other morphological characteristics or BW. Other researchers found that dam age influences birth weight[33][43]. The findings of[37] reported no difference was found between birth weight of lambs born from primiparous or multiparous ewes, contrary to other authors have mentioned that birth weight of lambs born from multiparous ewes is greater than that of lambs born to primiparous females. Young ewes had lighter lambs, while mature ewes had the heaviest lambs (Sulaiman et al., 2014)[30]. The reason for the lower average birth weight of lambs born from young ewes still growing, is probably due to the lower development of the reproductive organs of these ewes and the possible competition between the fetus and the ewes for nutrients which has not reached its adult size and continues to grow during gestation, or can be attributed to the fact that as the ewe reaches its maximum body development, and thus milk production as well as the expression of maternal ability increase[44].

Dam age had a significant effect on BW (P 0.01), SC, SW, and RH (P 0.05) of Assaf lambs at weaning (Figure 3). Kelman et al.[45] reported an effect of dam age on weaning weight, which increased with increasing dam age. Mohammadi et al.[46] reported that younger ewes produce lighter lambs at weaning due to a lower amount of milk produced compared to older ewes. In another study, Gardner et al.[44] reported no effect of dam age on weaning weight or the average weight gain from birth to weaning. The results of[40] showed that between 28 days - weaning, the best growth rate was observed in lambs of ewes by 5 and 6 years of age. On the whole growth period lambs whose mothers had 4 and 5 years showed the strongest increase in weight. According to[2], measurements data were directly related to dams' age, increasing up to the age of 5–6. The milk production of sheep, along with individuality (feed conversion), are the most influential factors of growth rate variation. Average daily gain after birth is much more tied to individual milk production, than the milk production of a particular breed. Milk production of sheep, according to the literature, increases until the age of 5-6 years when maximum production is recorded and followed by a slow decline (Ajoy et al., 2008). According to Paola et al. (2022), improving ewe condition seems to be more efficient than providing an additional source of solid food to lambs.

At marketing age, dam age has a significant (P<0.05) effect on BW, HW and SC with no effect on other morphological characteristics (Figure 3). Kelman et al.[45] reported that dam age affected BW at marketing age, with lambs born from 4–6-year-old dams tending to be heavier at 150 days of age. In addition, Gardner et al.[44] reported that the age of the dam affected BW at 150 days of lamb age. According to Souza et al.[47], after weaning, the animals are already independent from their dams and more dependent on their feeding, thus, depending more on their genetic potential for their growth.

The age of the dam significantly (P < 0.001) affected the multiple birth ratio of lambs (Table 5). Dams aged 3 to 5 years have an increasing multiple birth ratio, with dams aged 5 years having the highest multiple birth types, and dams aged 6 years having a higher multiple birth ratio than yearlings and 2 year olds. On the other hand, dam age did not affect the sex ratio.

The maternal effect has a pronounced influence on the rate of growth, but it represents 18.5 % of total variation at birth, and only 8.8% at weaning, which shows that it reduces with age. Highest maternal effect is linked to type of birth (80 %), followed by body weight (13.5 %) and age (6.5 %) (Ajoy et al., 2008). As indicated by the same authors, the maternal effect manifested at birth on lambs' weight decreased with age (Ajoy et al. 2008). Sheep age influences birth weight of lambs, because it is closely related to the weight of sheep, so as the sheep weight is smaller, lambs will be even lower (especially in sheep observed that most often are not fully developed before birth), but as a maternal effect, it is lost in time until the age of one year.

Correlation

Birth weight has high correlation coefficients with CG, moderate correlations with BL, SW, RW, WH and RH, while it has low correlation coefficients with HW, HL, shin circumference, RL, CD, FLH and RLH (Table 6). HW and length have low correlation coefficients with all morphological characteristics. CG has a high correlation with BL and a low to moderate correlation with other morphological characteristics. SC, BL, RL, CD and RW have low correlation with other morphological characteristics. RW has a high correlation with RW. WH has a high correlation with RH. FLH and RH have a high correlation with RLH. RW, wither height, FLH and RH have a high correlation with other morphological characteristics. In similar studies, Al-Tarayrah and Tabbaa[24] reported higher correlation coefficients between BL and many other morphological characteristics and between wither height and both RH and CG at birth.

At weaning, BW has high correlation coefficients with all morphological characteristics (Table 7). HW has a low to moderate correlation with all morphological characteristics. HL has a high correlation with CG, wither height, and RH. Also, CG has a high correlation with SC, RL, CD, SW, RW, WH, FLH and RH. SC and BL have a low to moderate correlation coefficients with all morphological characteristics. In addition, RL has high correlation coefficients with CD, SW and RW. CD has high correlation coefficients with SW, RW, WH and RH. SW has a high correlation coefficient with RW. RW has moderate correlation coefficients with WH, FLH and RH. WH and FLH have a high correlation with RH. RH has a high correlation with RLH. In addition, higher correlation coefficients were found between BW and BL, SW, RW, WH, RH and CG at 55–65 days of age[24]. Moderately to highly positive correlation coefficients were found between BW and each of BL, CG, RW, RH, SW and WH in Awassi lambs at 60 days of age[41]. At marketing, the BW has moderate correlation coefficients with CG, BL, SW, RW, WH, FLH, RLH and RH and low correlation coefficients with HW, HL, SC, RL, and CD (Table 8).

In addition, HW and length have low to moderate correlation coefficients with all morphological characteristics. CG has a high correlation coefficient with CD. BL and SC have low to moderate correlation coefficients with all morphological characteristics. RL and RW have low correlation coefficients with other morphological characteristics. CD has low to moderate correlation coefficients with other morphological characteristics. SW has a high correlation coefficient with RW. WH has high correlation coefficients with other morphological characteristics. FLH has high correlation coefficients with RLH and moderate ones with RH. RH has a moderate correlation coefficient with RLH. In addition, there were high correlation coefficients between BW and BL, SW, RW, wither height, RH and CG at 150 days of age[24]. Al-Azzawi et al.[41] found high correlation coefficients between BW and BL, CG, RW, RH, wither width, and wither height in Awassi lambs at six months of age. Chest girth and CD were reported to have the highest correlation coefficients with BW in lambs[48].

Prediction

Estimating the live weight using morphological characteristics is more practical and easier in rural areas where weight scales are not available. The birth weight of Assaf lambs was estimated by CG, RH, SW, CD, HW, SC and BL, it has an R-square of (R^2) (0.599 (Table 9). At weaning age, BW estimated by CG, CD, RLH and BL has the highest R^2 of 0.848 (Table 9). At marketing age, if we predict BW by RH, SW, RL, CD, FLH, CG and BL, it has R^2 of 0.582 (Table 9). The existence of a positive and significant correlation between live weight and body measurements supported the use of linear regression for live weight prediction[49]. Tyagi et al.[50] suggested determining the BWs of growing kids by using morphological characteristics taken over a period of the first three months of age. Melessea et al.[51] found CG, rump breadth, WH, BL, HW, and RL were revealed as independent variables in the female Thalli sheep's live BW prediction. The live weight prediction equations based on CG, WH, and BL were more accurate in female Nigerian Sokoto than in males[52].

Conclusions

Higher weight and morphological characteristics were obtained for lambs born in November than in other months. Therefore, adopting an earlier lambing season would be better in this aspect. Results also indicated that single lambs had heavier BWs and larger morphological characteristics at all ages. Consequently, it might be beneficial to make them fat for higher meat productivity. The results indicated that male lambs show larger morphological characteristics at all ages. Selecting lambs at advanced ages may aid in achieving rapid growth and thus increasing the profit of a sheep farm. The highest values for morphological characteristic correlations were obtained for weaning age. However, BW at weaning can be estimated with enough accuracy using some morphological characteristics.

Tables and Figures

Table 1. Overall averages and standard deviations of BW and morphological characteristics for Assaf lambs at different ages.

Variable	N	Birth	N	Weaning	N	Marketing
BW	204	6.01±1.35	87	20.40±5.39	101	32.08±5.29
HW	204	10.94±1.10	87	12.89±1.07	101	14.83±1.38
HL	204	15.31±1.29	87	20.44±1.93	101	22.68±1.78
CG	204	42.01±3.61	87	65.73±8.35	101	79.30±7.07
SC	204	6.44±0.64	87	7.33±0.69	101	8.11±0.70
BL	204	35.04±3.46	87	52.65±7.57	101	61.07±5.25
RL	204	9.44±1.69	87	17.07±2.88	101	18.90±2.28
CD	204	12.89±1.42	87	21.43±2.32	101	25.10±2.34
SW	204	9.06±1.22	87	15.07±2.43	101	18.90±1.78
RW	204	9.34±1.13	87	15.77±2.48	101	19.12±2.22
WH	204	42.04±2.93	87	55.36±5.12	101	61.46±3.57
FLH	204	28.57±2.38	87	36.50±2.87	101	39.31±2.10
RH	204	42.46±3.38	87	56.78±4.64	101	62.66±3.62
RLH	204	30.10±2.44	87	38.17±2.50	101	40.52±2.28

BW: body weight, HW: head width, HL: head length, CG: Chest Girth, SC: shin circumference, BL: body length, RL: rump length, CD: chest depth, SW: shoulder width, RW: rump width, WH: withers height, FLH: foreleg height, RH: rump height, RLH: rear leg height.

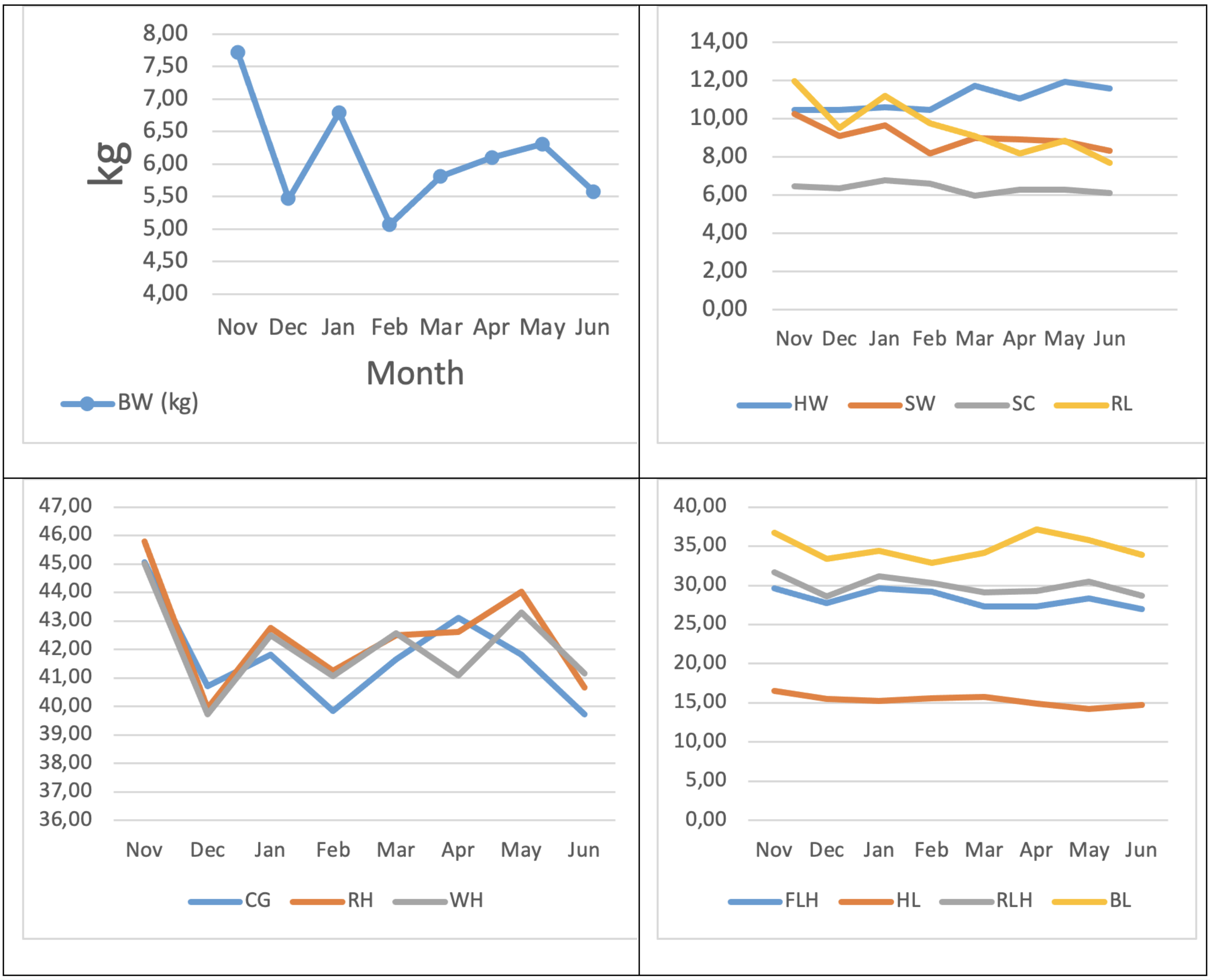

Figure 1. Effect month of birth on BW: birth weight (**A**) HW: head width, SW: shoulder width, SC: shin circumference, RL: rump length (**B**), CG: chest girth, WH: wither height, RH: rump height (**C**), FLH: foreleg height, HL: head length, RLH: rear leg height, BL: body length (**D**).

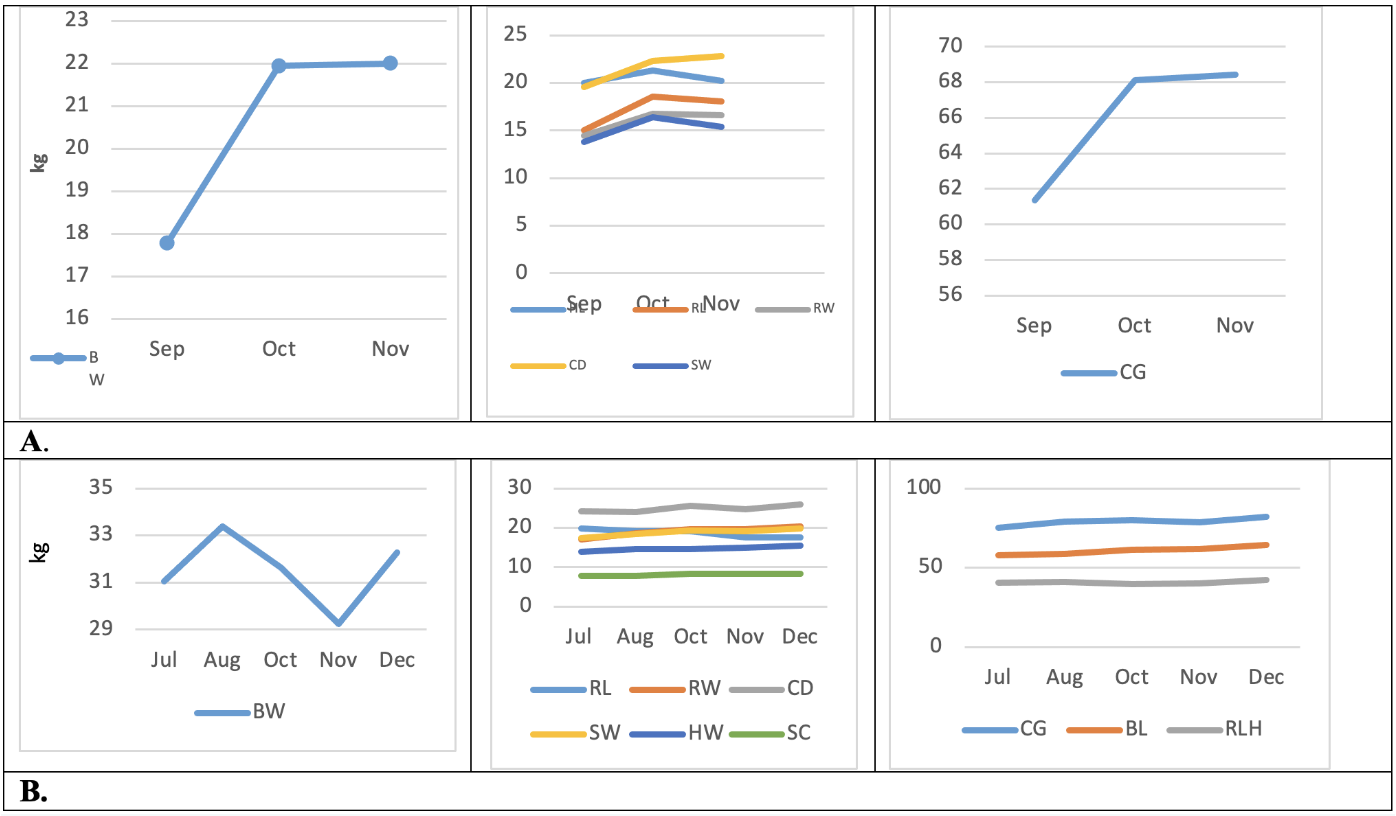

Figure 2.A. Effect month of birth on BW: body weight, HL: head length, RL: rump length, RW: rump width, CD: chest depth, SW: shoulder width (**A**), CG: chest girth. **B.** Effect month of birth on BW: body weight, RL: rump length, RW: rump width, CD: chest depth, SW: shoulder width, HW: head width, SC: shin circumference, CG: chest girth, BL: body length, RLH: rear leg height.

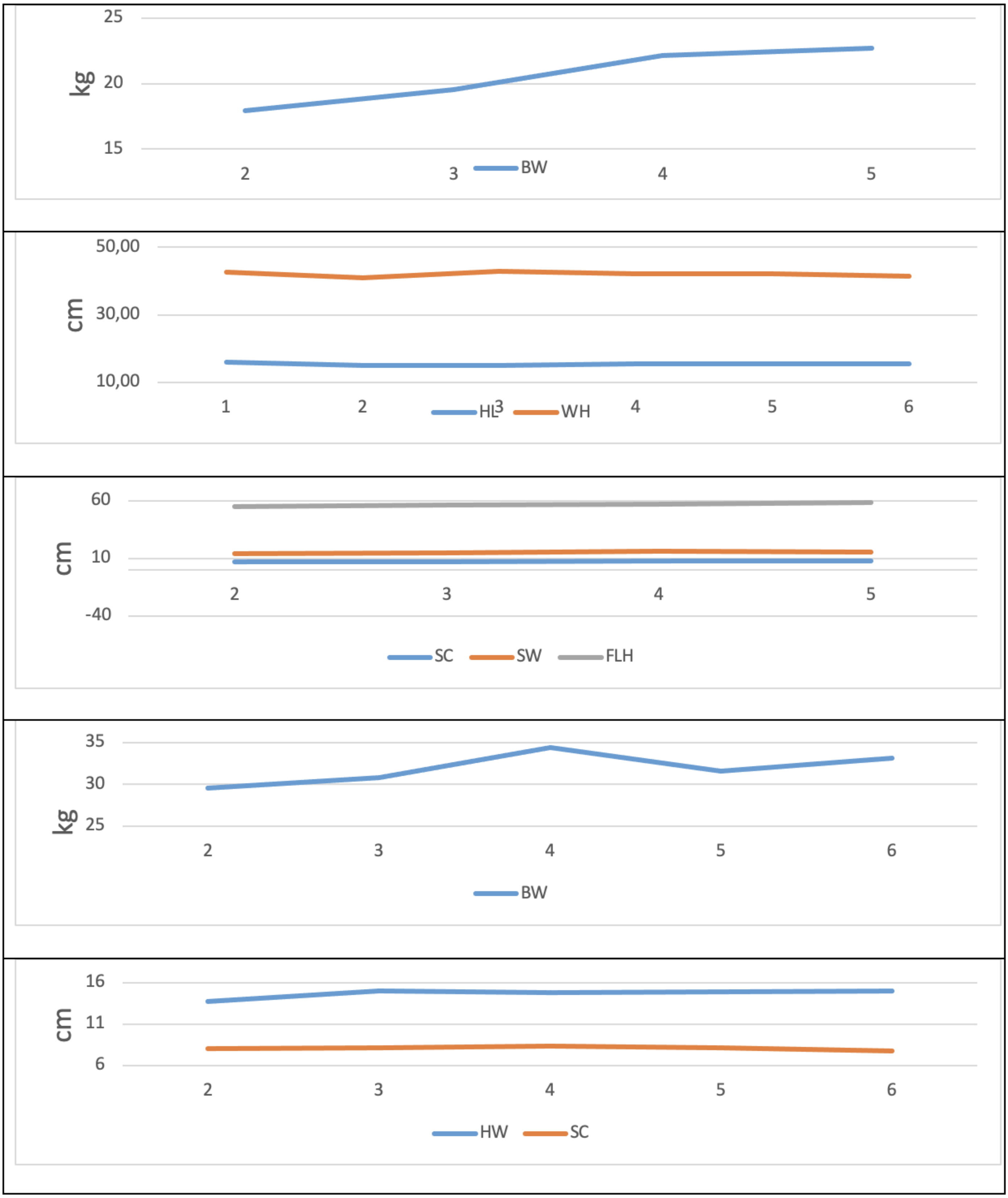

Figure 3. Effect age of dam on BW: body weight (A), HL: head length, WH: wither Height, SC: shin circumference, SW: shoulder width (B) at weaning and Effect age of dam on BW: body weight, FLH: foreleg height (C), HW: head width, SC: shin circumference (B) at marketing

Table 2. Effect of different factors on BW and morphological characteristics for Assaf lambs at birth.

Variable	N	BW	HW	HL	CG	SC	BL	RL	CD	SW	RW	WH	FLH	RH	RLH
Birth type (P-value)		0.040	0.815	0.2568	0.0015	0.078	0.0086	0.0993	0.4207	0.0206	0.1127	0.0085	0.0328	0.0883	0.011
Single	**85**	6.43±0.14a	11.07±0.11	15.53±0.14	43.06±0.39a	6.49±0.07	35.82±0.37	9.85±0.17	13.13±0.17	9.38±0.14	9.53±0.13	42.48±0.30a	28.73±0.26a	43.01±0.35	30.54±0.27a
Twines	**99**	6.24±0.14ab	10.98±0.11	15.35±0.14	42.05±0.39a	6.40±0.07	35.22±0.37	9.68±0.17	12.97±0.17	9.05±0.14	9.30±0.13	42.85±0.30a	28.74±0.26a	42.95±0.35	30.37±0.27a
Triple	**20**	5.64±0.29b	11.04±0.23	15.03±0.29	40.05±0.78b	6.14±0.14	33.35±0.73	9.05±0.34	12.66±0.34	8.61±0.27	8.98±0.26	40.81±0.60b	27.33±0.52b	41.36±0.70	28.76±0.54b
Sex (P-value)		0.255	0.704	0.7701	0.3526	0.044	0.5506	0.1985	0.9738	0.4673	0.0799	0.5002	0.2012	0.0947	0.6592
Female	**100**	6.21±0.15	11.00±0.12	15.28±0.15	41.94±0.40	6.43±0.07a	34.93±0.38	9.66±0.18	12.92±0.17	9.07±0.14	9.41±0.14	42.17±0.31	28.47±0.27	42.80±0.37	29.96±0.28
Male	**104**	6.01±0.15	11.05±0.12	15.33±0.16	41.50±0.42	6.26±0.08b	34.66±0.39	9.39±0.18	12.92±0.18	8.96±0.15	9.13±0.14	41.92±0.32	28.07±0.28	42.08±0.38	29.82±0.29
R-Square		0.270	0.300	0.187	0.235	0.272	0.272	0.325	0.087	0.191	0.105	0.319	0.230	0.289	0.182

BW: body weight, HW: head width, HL: head length, CG: chest girth, SC: shin circumference, BL: body length, RL: rump length, CD: chest depth, SW: shoulder width, RW: rump width, WH: wither height, FLH: foreleg height, RH: rump height, RLH: rear leg height.

Table 3. Effect of different factors on BW and morphological characteristics for Assaf lambs at weaning.

Variable	N	BW	HW	HL	CG	SC	BL	RL	CD	SW	RW	WH	FLH	RH	RLH
Birth type P-value		0.0186	0.6503	0.0017	0.1524	0.0987	0.3578	0.2735	0.0372	0.2946	0.2753	0.001	0.2733	0.0072	0.0108
Single	**47**	21.80±0.65a	13.01±0.15	21.12±0.25a	67.21±1.09	7.48±0.10	53.87±1.09	17.51±0.35	22.03±0.27a	15.48±0.32	16.23±0.34	57.27±0.68a	36.98±0.42	58.16±0.61a	38.83±0.33a
Multiple	**40**	19.36±0.74b	12.91±0.17	19.85±0.28b	64.73±1.24	7.23±0.11	52.29±1.23	16.91±0.39	21.12±0.31b	14.95±0.36	15.64±0.39	53.60±0.77b	36.26±0.48	55.51±0.69b	37.47±0.38b
Sex P-value		0.1593	0.0017	0.7141	0.211	0.0121	0.0666	0.7205	0.0199	0.9344	0.2683	0.0112	0.1035	0.0313	0.0154
Female	**45**	19.89±0.67	12.59±0.16b	20.42±0.26	64.94±1.13	7.17±0.10b	51.57±1.13	17.11±0.36	21.09±0.28b	15.23±0.33	15.65±0.36	54.11±0.71b	36.10±0.44	55.83±0.63b	37.54±0.34b
Male	**42**	21.27±0.68	13.33±0.16a	20.56±0.26	67.00±1.14	7.54±0.10a	54.59±1.14	17.30±0.36	22.06±0.29a	15.19±0.33	16.22±0.36	56.76±0.71a	37.14±0.44	57.83±0.64a	38.76±0.35a
R-Square		0.445	0.233	0.357	0.342	0.244	0.208	0.440	0.465	0.342	0.268	0.319	0.181	0.332	0.323

BW: body weight, HW: head width, HL: head length, CG: chest girth, SC: shin circumference, BL: body length, RL: rump length, CD: chest depth, SW: shoulder width, RW: rump width, WH: wither height, FLH: foreleg height, RH: rump height, RLH: rear leg height.

Table 4. Effect of different factors on BW and morphological characteristics for Assaf lambs at marketing.

Variable	N	BW	HW	HL	CG	SC	BL	RL	CD	SW	RW	WH	FLH	RH	RLH
Birth type P-value		0.0151	0.3516	0.9493	0.9322	0.3221	0.2546	0.9664	0.6007	0.5574	0.5057	0.1848	0.5425	0.0268	0.0269
Single	**37**	33.09±0.81a	14.82±0.21	22.53±0.32	78.93±1.10	8.16±0.11	61.31±0.81	18.63±0.40	24.99±0.39	18.91±0.28	19.18±0.35	61.92±0.65	39.36±0.36	63.65±0.64a	41.19±0.40a
Multiple	**64**	30.74±0.60b	14.59±0.16	22.51±0.24	79.04±0.81	8.03±0.08	60.21±0.60	18.65±0.30	24.75±0.29	18.71±0.21	18.90±0.26	60.90±0.48	39.09±0.27	61.96±0.47b	40.14±0.30b
Sex P-value		0.5068	0.0458	0.0453	0.2888	<.0001	0.0181	0.0413	0.3258	0.1731	0.4847	0.5138	0.0312	0.4255	0.6916
Female	**41**	31.57±0.83	14.43±0.22b	22.10±0.34b	79.74±1.13	7.78±0.11b	59.51±0.84b	18.10±0.41b	24.62±0.41	18.56±0.29	18.88±0.36	61.14±0.67	38.71±0.38b	63.13±0.66	40.56±0.41
Male	**60**	32.26±0.63	14.98±0.16a	22.94±0.25a	78.24±0.85	8.41±0.08a	62.02±0.63a	19.17±0.31a	25.12±0.31	19.06±0.22	19.20±0.27	61.68±0.51	39.74±0.28a	62.47±0.50	40.77±0.31
R-Square		0.408	0.417	0.154	0.388	0.385	0.391	0.214	0.288	0.346	0.359	0.157	0.235	0.213	0.220

BW: body weight, HW: head width, HL: head length, CG: chest girth, SC: shin circumference, BL: body length, RL: rump length, CD: chest depth, SW: shoulder width, RW: rump width, WH: wither height, FLH: foreleg height, RH: rump height, RLH: rear leg height.

Table 5. Effect of dam age on frequency of birth type and sex.

Variable	Dam age							Chi-Square (P value)
Type of birth	**1**	**2**	**3**	**4**	**5**	**6**	Total	
Single	71.43	69.23	42.86	40	26	46.27	45.81	0.0002
Multiple	28.57	30.77	57.14	60	74	53.73	54.19	
Sex								
Female	71.43	48.08	51.65	46.67	40	43.28	47.6	0.3614
Male	28.57	51.92	48.35	53.33	60	56.72	52.4	
N	14	52	91	60	50	67	334	

Table 6. Correlation of BW and morphological characteristics at birth.

Variable	HW	HL	CG	SC	BL	RL	CD	SW	RW	WH	FLH	RH	RLH
BW	0.24**	0.13	0.68**	0.24**	0.58**	0.30**	0.31**	0.46**	0.47**	0.48**	0.29**	0.52**	0.37**
HW		0.15*	0.19**	-0.07	0.14	-0.08	0.17*	0.06	0.14*	0.19**	-0.10	0.22**	0.02
HL			0.16*	-0.04	0.03	0.24**	0.11	0.12	0.08	0.13	-0.01	0.09	0.03
CG				0.18*	0.61**	0.28**	0.23**	0.39**	0.46**	0.42**	0.18**	0.47**	0.26**
SC					0.09	0.17*	0.16*	0.26**	0.3**	0.22**	0.26**	0.22**	0.28**
BL						0.22**	0.13	0.32**	0.41**	0.34**	0.21**	0.4**	0.31**
RL							0.21**	0.37**	0.37**	0.27**	0.38**	0.25**	0.23**
CD								0.13	0.19**	0.27**	0.19**	0.24**	0.22**
SW									0.6**	0.29**	0.24**	0.32**	0.23**
RW										0.42**	0.25**	0.36**	0.27**
WH											0.45**	0.74**	0.48**
FLH												0.43**	0.60**
RH													0.51**

*N=204, BW: body weight, HW: head width, HL: head length, CG: chest girth, SC: shin circumference, BL: body length, RL: rump length, CD: chest depth, SW: shoulder width, RW: rump width, WH: wither height, FLH: foreleg height, RH: rump height, RLH: rear leg height. **p < 0.01, *p < 0.05.*

Table 7. Correlation of BW and morphological characteristics at weaning.

Variable	HW	HL	CG	SC	BL	RL	CD	SW	RW	WH	FLH	RH	RLH
BW	0.43**	0.61**	0.87**	0.54**	0.50**	0.68**	0.82**	0.78**	0.70**	0.62**	0.61**	0.71**	0.55**
HW		0.26*	0.44**	0.44**	0.26*	0.30**	0.52**	0.42**	0.45**	0.40**	0.3**	0.36**	0.16
HL			0.59**	0.24*	0.37**	0.36**	0.51**	0.52**	0.41**	0.64**	0.51**	0.73**	0.39**
CG				0.61**	0.38**	0.74**	0.8**	0.81**	0.77**	0.65**	0.63**	0.72**	0.44**
SC					0.22*	0.5**	0.57**	0.56**	0.59**	0.42**	0.47**	0.39**	0.25*
BL						0.31**	0.43**	0.36**	0.30**	0.36**	0.42**	0.41**	0.43**
RL							0.68**	0.69**	0.62**	0.34**	0.46**	0.50**	0.31**
CD								0.78**	0.80**	0.62**	0.56**	0.66**	0.34**
SW									0.87**	0.55**	0.56**	0.58**	0.31**
RW										0.59**	0.52**	0.56**	0.27**
WH											0.58**	0.78**	0.50**
FLH												0.69**	0.52**
RH													0.57**

*N=87, BW: body weight, HW: head width, HL: head length, CG: chest girth, SC: shin circumference, BL: body length, RL: rump length, CD: chest depth, SW: shoulder width, RW: rump width, WH: wither height, FLH: foreleg height, RH: rump height, RLH: rear leg height. **p < 0.01, *p < 0.05.*

Table 8. Correlation of BW and morphological characteristics at marketing.

Variable	HW	HL	CG	SC	BL	RL	CD	SW	RW	WH	FLH	RH	RLH
BW	0.28**	0.26**	0.5**	0.24*	0.41**	0.21*	0.26**	0.51**	0.43**	0.45**	0.45**	0.52**	0.40**
HW		0.34**	0.39**	0.38**	0.52**	-0.08	0.53**	0.37**	0.37**	0.22*	0.24*	0.30**	0.27**
HL			0.11	0.12	0.18	0.10	0.20*	0.08	0.06	0.37**	0.13	0.40**	0.23*
CG				0.29**	0.53**	0.05	0.66**	0.55**	0.57**	0.31**	0.37**	0.49**	0.34**
SC					0.43**	0.1	0.38**	0.38**	0.41**	0.04	0.31**	0.12	0.22*
BL						-0.03	0.54**	0.55**	0.50**	0.23*	0.25*	0.29**	0.37**
RL							0.07	-0.05	-0.04	0.07	0.10	0.04	0.05
CD								0.39**	0.39**	0.33**	0.36**	0.48**	0.33**
SW									0.77**	0.08	0.19	0.20*	0.17
RW										-0.02	0.11	0.19	0.06
WH											0.69**	0.79**	0.6**
FLH												0.53**	0.66**
RH													0.51**

*N=101, BW: body weight, HW: head width, HL: head length, CG: chest girth, SC: shin circumference, BL: body length, RL: rump length, CD: chest depth, SW: shoulder width, RW: rump width, WH: wither height, FLH: foreleg height, RH: rump height, RLH: rear leg height. **p < 0.01, *p < 0.05.*

Table 9. Prediction of BW at birth, weaning and marketing.

Dependent variable	Birth weight	P value F-test	Partial R-square	Dependent variable	Weaning weight	P value F-test	Partial R-square	Dependent variable	Marketing weight	P value F-test	Partial R-square
Intercept	-10.41±1.12	<.0001		Intercept	-34.80±3.75	<.0001		Intercept	-50.90±8.23	<.0001	
Chest Girth	0.14±0.02	<.0001	0.465	Chest Girth	0.33±0.05	<.0001	0.765	Rump height	0.55±0.13	<.0001	0.275
Rump height	0.06±0.02	0.005	0.052	Chest depth	0.72±0.171	<.0001	0.043	Shoulder width	1.07±0.26	<.0001	0.173
Shoulder width	0.18±0.06	0.002	0.031	Rear leg height	0.36±0.11	0.001	0.034	Rump length	0.50±0.16	0.002	0.046
Chest depth	0.12±0.05	0.012	0.017	Body length	0.07±0.04	0.059	0.007	Chest depth	-0.82±0.22	0	0.027
Head width	0.10±0.06	0.079	0.005					Foreleg height	0.45±0.20	0.029	0.027
Shin circumference	0.15±0.10	0.149	0.004					Chest Girth	0.15±0.08	0.049	0.021
Body Length	0.08±0.02	0	0.004					Body length	0.15±0.09	0.095	0.013
R-square	0.599			R-square	0.848			R-square	0.582		
MSE	0.761			MSE	4.62			MSE	12.597		
RMSE	0.872			RMSE	2.15			RMSE	3.549		
Number	204			Number	87			Number	101		

BW= -10.41 + 0.14 CG +0.06 RH +0.18 SW +0.12 CD + 0.10 HW + 0.15 SC +0.08 BL

WW= -34.80 +0.33 CG +0.72 CD +0.38 RLH +0.07 BL

MW= -50.90 + 0.55 RH + 1.10 SW + 0.50 RL – 0.82 CD + 0.45 FLH + 0.16 CG + 0.15 BL

Statements and Declarations

Conflicts of interest

The authors declare no competing interests.

Author contribution

All authors contributed to the study conception and design. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Azzam K. Aljamaeen: Data collection & investigation, measures taking, writing, draft, writing.

Mohammad J. Tabbaa: Methodology & supervision, data analysis, draft, writing & review.

Raed M. Al-Atiyat: Methodology & supervision, writing & review.

Hosam H. Titi: Data discussion, supervision, writing, review & editing.

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Data availability

The datasets generated during and/or analyzed during the current study are not publicly available because they are data that were collected manually during the experiment and stored by the researchers in their personal files but are available from the corresponding author upon reasonable request.

Ethics approval

The Research Animal Care and Use Committee gave its approval to the experimental design and procedures. Scientific Research Ethics Committee, Form 4.

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