Age and sex changes in the mass, length and width of the scapula of Romanov sheep during ontogenensis

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Abstract. The article presents results of morphometric studies of the scapula in the ontogenesis of Romanov sheep. The material was scapula of two-month feta, animals aged up to 12 months and 5-6-year-old sheep. The interval between the ages at the uterine stage was 1 month, and after birth – 3 months. The scapula of two male and two female animals were studied in each age group. In each scapula without scapular cartilage, the mass, length and width were studied. The average data for each indicator and each sex were compared. The results showed that absolute indices of the scapula, i.e., the mass, length and width in male animals significantly exceed those in the female ones. A growth in the scapula mass, length and width is subject to the general biological laws of reducing intensity with aging, i.e., at the uterine stage, it is more intensive for male than for female animals. In contrast to the width, the scapula length significantly increases at the uterine stage. By the one-year-old age, no scapula does not reach its definitive state. One can assume that in females the scapula width will reach its final size earlier, while in males, the scapula mass and length will reach their final values earlier.

1. Introduction
The skeleton of domestic animals has been studied by many researchers [1-6], because people have to deal with its various disorders (underdevelopment, loss of strength, lacking or excessive mineralization) that cause bone and general diseases. Despite its rigidity, the skeleton is an extremely labile living system determining the well-being of the whole organism [7]. The state of the skeleton is the most important indicator of vitality and health. The study of age and sex characteristics of the growth in scapula mass, length and width during ontogenesis of Romanov sheep is crucial. The scapula of animals is a link between the breast limb and the axial skeleton which affects growth characteristics. The scapula is studied together with other bones of the thoracic limb ignoring gender characteristics [8-10].

The article aims to establish general patterns of growing morphometric parameters of the scapula of Romanov sheep during ontogenensis accounting for sex and age characteristics.

2. Materials and methods
The material was scapula of two-month feta, animals aged up to 12 months and 5-6-year-old sheep. At the uterine stage, the interval between the ages was 1 month, and after birth – 3 months. The scapula of
two male and two female animals were studied in each age group. All animals were raised in Ivanovo region. All the bones were immediately released from the surrounding tissues, including scapular cartilage, thoroughly cleaned and treated. The bones of two-month-old feta were weighed with an error of 0.001 g; the bones of six-month feta were weighed with an error of 0.1 g. Using a caliper, the scapula length was measured from the base to the articular cavity; the width was measured between cranial and caudal angles. The error was 0.1 mm.

The morphometric data were analyzed [11] to identify general patterns of scapula growth. The growth ratio which was determined by dividing morphometric parameters at one age by similar indicators of the previous age was calculated. The degree of scapula maturity at a particular age was determined. Morphometric parameters at any age were divided by the same parameters in adult animals. Sex differences were revealed by dividing morphometric parameters in males by the same parameters in females. The percentage ratio of the scapula length to its width in males and females was calculated.

3. Results and discussion

Table 1 shows that all the morphometric parameters of the scapula throughout the entire ontogenesis, as well as in both sexes, increase, reaching a maximum value in adult animals. Moreover, each indicator varies with age unequally.

| Age, months | Males | Females |
|-------------|-------|---------|
|             | Mass, g | Length, cm | Width, cm | Length, cm | Width, cm |
| Feta        | 0.048  | 1.17     | 0.81      | 0.042      | 1.13      | 0.77     |
| 2           | 0.65 ±0.1 | 3.20 ±0.1 | 2.10 ±0.1 | 0.58 ±0.1 | 3.06 ±0.1 | 1.99 ±0.1 |
| 3           | 2.78 ±0.2 | 5.23 ±0.2 | 3.21 ±0.1 | 2.06 ±0.1 | 4.91 ±0.1 | 3.04 ±0.1 |
| 4           | 6.49 ±0.2 | 6.79 ±0.2 | 4.15 ±0.1 | 6.31 ±0.2 | 6.64 ±0.2 | 4.05 ±0.1 |
| Newborn     | 23.18±0.6 | 10.60±0.3 | 7.10±0.2  | 16.05±0.5 | 9.18±0.2  | 6.16±0.2  |
| Lambs       | 32.0±0.7  | 11.63±0.3 | 8.23±0.2  | 30.4±0.6  | 11.52±0.3 | 8.02±0.2  |
| 6           | 46.3±0.9  | 13.32±0.3 | 9.22±0.3  | 38.9±0.7  | 12.46±0.2 | 8.94±0.3  |
| 9           | 54.7±0.8  | 14.84±0.3 | 10.05±0.4 | 47.3±0.8  | 13.07±0.4 | 9.36±0.3  |
| 12          | 73.1±0.9  | 16.50±0.4 | 11.83±0.3 | 66.6±0.10 | 14.49±0.3 | 10.11±0.4 |
| Adult animals |       |          |           |            |           |          |

In males at any age of ontogenesis, the scapula mass usually (p ≤ 0.01) exceeds that in females. If we calculate the ratio of the scapula mass in males to its mass in females, we find that it is most pronounced up to the fourth month of the uterine development, when it increases from 14% to 35%; before birth, it decreases to 3%. This decrease is due to the fact that in the last month of pregnancy, the animal is not strong enough to keep the large male scapula mass. Three months after birth, this weight advantage returns to 44%. 3-6 months after birth, growth in the scapula in both sexes decreases due to their puberty, and the difference in the scapula mass between females and males decreases up to 3%. 6 months after birth, the male scapula weight grows at a faster rate compared with the female one, which also affects an increase in its relative advantage up to 10-19%.

The dynamics of changes in the scapula length and width is synchronous with the dynamics of changes in the scapula mass. At the uterine stage, the male scapula length and width exceed the female ones by 5-7%. Before birth, they decrease up to 2%, and during the first 3 months after birth, they increase up to 15%. Six months after birth, they decrease and are maintained at the same level - 0.1-0.7% until the ninth month. Later, this advantage increases up to 7–17%.

Before birth, the length grows more rapidly than the width. Therefore, the ratio of length to width increases. If in male and female two-months-old feta, this ratio is 44% and 46% more, in newborns of
both sexes, it is 64%. After birth, on the contrary, the scapula grows more rapidly in width, and the ratio of scapula length to its width decreases all the time, reaching 139% in adult males and 143% in adult females. These data indicate that the shape of the scapula in males and females does not change. Thus, in males and females, the ratio of the length to the width varies from 139 to 164%.

Table 2 shows changes in the growth of the scapula parameters. They obey the general biological laws, i.e. they are more intensive at the uterine stage. If for the entire prenatal ontogenesis, the male scapula mass increased by 135, and the female one increased by 150 times. Despite the fact that in ontogenetic development, the absolute mass of the male scapula is heavier than the female one, its growth in males in the uterine development stage will be less intensive. Both at the uterine and postnatal stages, the mass growth is intensive, and then it gradually decreases (p ≤ 0.01).

Table 2. Age and sex changes in the coefficient of scapula mass, length and width growth in the ontogenesis of Romanov sheep.

| Age, months  | Males          | Females         |
|--------------|----------------|-----------------|
|              | Mass, g        | Length, cm      | Width, cm     | Mass, g        | Length, cm      | Width, cm     |
| Feta:        |                |                 |               |               |                 |               |
| 2-3          | 13.54          | 2.74            | 2.59          | 13.81          | 2.71            | 2.58          |
| 3-4          | 4.58           | 1.63            | 1.53          | 3.55           | 1.60            | 1.53          |
| 4            | 2.33           | 1.30            | 1.29          | 3.06           | 1.35            | 1.33          |
| Newborn lambs|                |                 |               |               |                 |               |
| 3-6          | 3.57           | 1.56            | 1.71          | 2.54           | 1.38            | 1.52          |
| 6-9          | 1.38           | 1.10            | 1.16          | 1.89           | 1.25            | 1.30          |
| 9-12         | 1.18           | 1.16            | 1.09          | 1.22           | 1.08            | 1.11          |
| 12-Adult animals| 1.34       | 1.11            | 1.18          | 1.41           | 1.11            | 1.08          |
| For postnatal ontogenesis| 135.2| 5.80     | 4.94 | 150.2 | 5.88 | 5.26 |
| For postnatal ontogenesis| 11.26| 2.43     | 2.85 | 10.56 | 2.18 | 2.50 |

Almost the same patterns are observed for the scapula length and width. If at the uterine stage, the scapula length growth coefficient does not differ for males and females (5.80 and 5.88), after birth, the scapula grows with much greater intensity in males (the growth coefficient is 2.43) compared with females (the growth coefficient is 2.18). In both sexes, at the uterine development stage, the scapula length growth is more intensive than the scapula width growth.

Table 3 shows the degree of maturity of individual indicators at a given age relative to the same indicators in adult sheep. In a two-month fetus, the relative weight is almost 100 times less. During the third month, due to the accelerated growth of the scapula mass, differences in the relative mass, length and width decrease up to 20 times. At subsequent ages, it is even more reduced. None of the indicators reach final values at the age of one year. In females, the scapula width quickly reaches its definitive state, and in males, the scapula mass and length quickly reach their final values.

As for sex differences in the scapula growth, at the uterine development stage, the relative weight was higher in males. Later, it was higher in female newborn lambs; then it was higher in males, and in nine-month-animals, it was higher in males. In males, the length approaches its final value faster than the width; in females, this lasts for 9 months, and then the width grows faster.
Table 3. Age and sex changes in scapula weight, length and width of relative to those in adult sheep, %.

| Age, months | Males, mass, g | Length, cm | Width, cm | Females, Mass, g | Length, cm | Width, cm |
|-------------|----------------|------------|-----------|-----------------|------------|-----------|
| Feta        | 0.066          | 7.1        | 6.8       | 0.063           | 7.8        | 7.6       |
| 2           | 0.89           | 19.4       | 17.8      | 0.87            | 21.1       | 19.6      |
| 3           | 3.80           | 31.6       | 27.1      | 3.09            | 33.9       | 30.1      |
| 4           | 8.88           | 41.1       | 35.1      | 9.47            | 45.8       | 40.1      |
| Newborn lambs | 31.7        | 64.2       | 60.0      | 24.1            | 63.3       | 60.9      |
| 6           | 43.8           | 70.5       | 69.6      | 45.6            | 79.6       | 79.3      |
| 9           | 63.3           | 80.7       | 77.9      | 58.4            | 86.0       | 88.4      |
| 12          | 74.8           | 89.9       | 85.0      | 71.0            | 90.2       | 92.6      |
| Adult animals | 100.0        | 100.0      | 100.0     | 100.0           | 100.0      | 100.0     |

4. Conclusion

- At any age, in males, the absolute scapula parameter values (mass, length and width) exceed those in females.
- The growth in the scapula mass, length and width obeys the general biological laws of reducing intensity with age.
- In the prenatal ontogenesis, the male scapula mass increases less intensively compared with the female one; after birth, it increases more intensively.
- In both sexes, at the uterine stage, the scapula length grows more intensively compared with the scapula width; after birth, the situation is quite opposite.
- At the age of one year, none of the scapula indicators reaches its final values.

References

[1] Isaenkov E A, Pronin V V, Volkova M V, Timofeeva G S, Dyumin M S, Frolova L S 2014 Age-related changes in the weight and length of the bones of the digits of Romanov sheep in prenatal ontogenesis RVJ AB. 2 8–10
[2] Isaenkov E A, Pronin V V, Volkova M V, Timofeeva G S, Dyumin M S 2015 Structural rearrangements of the bone skeleton of the digits of Romanov sheep in postnatal ontogenesis RVJ AB. 4 14–16
[3] Isaenkov E A 1997 Anatomical and physiological changes in the peripheral skeleton in Romanov sheep during ontogenesis, Dissertation, St. Petersburg, 28 p.
[4] Chen H, Hu B, Lv X, Zhu S, Zhen G, Wan M, Cao X 2019 Prostaglandin E2 mediates sensory nerve regulation of bone homeostasis. Nature Communications, 10(1)
[5] Chang S H, Mori D, Kobayashi H, Mori Y, Nakamoto H, Okada K, Saito T 2019 Excessive mechanical loading promotes osteoarthritis through the gremlin-1–NF-κB pathway. Nature Communications, 10(1)
[6] Wang J, Xiao D, Wu H, Ye M, Li X 2015 Experimental and clinical analysis of a posterolateral lumbar appendicular bone graft fusion. Int. J. of Clinical and Experimental Medicine 8(12)
[7] Schwartz S S 1968 The method of morphophysiological indicators in the ecology of terrestrial vertebrates Proceedings of the Institute of Plant and Animal Ecology. vol. 58 (Sverdlovsk) p. 387
[8] Matsuo T, Morita F, Tani D, Nakamura H, Higurashi Y, Ohgi J, Wada N 2019 Anatomical variation of habitat-related changes in scapular morphology. J. of Veterinary Medicine Ser. C: Anatomia Histologia Embryologia 48(3) 218–227
[9] Sears K E, Bianchi C, Powers L, Beck A L 2013 Integration of the mammalian shoulder girdle within populations and over evolutionary time. *J. of Evolutionary Biology* **26**(7) 1536–1548

[10] Valasek P, Theis S, Krejci E, Grim M, Maina F, Shwartz Y, Patel K 2010 Somitic origin of the medial border of the mammalian scapula and its homology to the avian scapula blade. *J. of Anatomy* **216**(4) 482–488

[11] Yakovlev V D, Yakovleva O A 2014 *Biometric Processing of Experimental Data Tutorial.* (Moscow: Lennex Corp) p. 173