

Functional Morphology of Horns and Hooves of Caucasian Tur (*Capra caucasica*) and Their Significance in the Process of Adaptation to the Highlands of Shahdag National Park of Azerbaijan

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Abstract Horns and hooves of even-toed animals adapted to the highlands play an irreplaceable role in their life activity. These animals inhabit in extreme situations; any recklessness while rescuing from enemies or moving around, depending on the environmental conditions, can result in death. Thanks to horns and hooves they can orientate and save themselves falling from highlands. So far, the researchers have paid special attention to ecological issues like the structure of tur population, fluctuations in the number of individuals in the population, impact of different factors on fluctuation dynamics in open spaces and reserves [1,2,3]. However, morphological investigation of Caucasian turs' organs and systems which has an adaptive and evolutionary significance have not been thoroughly investigated yet.

Keywords: Caucasian tur, horns, hoofs, shingles, rims, corolla, wall, sole

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1. Introduction

There were not many studies conducted on even-toed animals inhabiting in highlands of Caucasus, therefore the literature is scarce [1]. The reason behind is that the location where the Caucasian turs inhabit is hardly accessible by the investigators doing research. Furthermore, these unique and exotic animals are included in the red list of several middle east countries, as well as in the red book of Azerbaijan as rare and extinct type of animals and therefore protected carefully. Based on these circumstances, it is only possible to shoot and make an experimental research on these animals during certain period of the year without breaking the law. Hunting and conducting studies on the animals are allowed with a state license exclusively from May until September when labor and other important biological processes end. The aim of this study is to investigate the functional morphology of horns and hooves of the front and back extremities of the Caucasian tur, to determine their role in orientation, as well as adaptation of these animals to difficult conditions of highlands.

2. Materials and Methods

The study was conducted on 2016-2017 in the highlands of north-east Azerbaijan, under the permission

of the Ministry of Ecology and Natural Resources of Azerbaijan in Shahdagh, Bazar-duzu and Baba-dagh areas adjacent to Shahdagh National Park where Caucasian turs habitate. 8 pairs of hooves of front and back extremities of the Caucasian tur-*Capra caucasica* and their horns captured in Shahdagh National Park were used as materials. Most of the studied turs were males at the age of 1, 6, 4 and 8 captured during trophy hunting. The main aim of choosing the materials in increasing aspect, is to trace the morphological changes of horns and hooves in comparative way. For this purpose, hooves and horns of studied materials were measured. All Caucasian turs were shot by hunters under a state license (license series and number- AA № 01081) during August, September and October. In addition, we used corpses of animals died for unknown reasons found in high mountains and examined skeletons which are being preserved in the osteological museums at the department of Medical biology and genetics of Azerbaijan Medical University.

3. Results and Discussion

Caucasian turs are large goats which mainly live in the subalpine and alpine belt of the Greater Caucasus mountains within 800 to 4200 meters above sea level. Latin name of Caucasian tur is "*Capra caucasica*".

However, there are different names of Caucasian tur, like south Caucasian tur – *Capra caucasica*, the Kuban or

western Caucasian tur – *Capra Caucasica*, [1,3,4,12], Caucasian mountain tur – *Capra Caucasica* [5,6,7], Caucasian mountain goat [8,11,13,14], Kuban tur – *Capra Caucasica*, [6,9], Severtsov's tur – *Capra severtzovi* Menzb.[10] etc. mentioned in the literature.

Taxonomists distinguish between two types of turs – the Kuban/Caucasian and Dagestan tur. These animals differ from each other in the shape of their horns. The Kuban turs have arched horns with sharp tips curved inwards, whereas Dagestan tur has thicker horns in the form of elongated spiral with tips pointing backwards and upwards. Other taxonomists consider both as the same biological species. There are not significant differences between these two types of turs apart from the differences in horns and in other minor morphological features. In addition, Caucasian tur has 2 subspecies which are often considered as two different species – Severtsov's tur (*Capra severtzovi* Menzb.) and Dagestan tur (*Capra cylindricornis* Blyth.). However, there is an opinion in the literature that *C.Caucasia* represents either a crossbreeding or transitional form between Severtsov tur and Dagestan tur on the border of the distribution areas of two species. Nevertheless, Caucasian turs differ from other goats in larger size and massive constitution. Thus, the systematic relationship between the Caucasian turs have not been fully elucidated and in our opinion, molecular-genetic research is required.

Caucasian turs adhere to steep rocky slopes thanks to their powerful limbs and hooves. Their horns play an important role in their movement on inaccessible rocky cliffs, along with hooves. Horns are clearly visible in males as well as in females, but female horns are smaller in size. The main function of horns is to attack and defend themselves before mating when they fight for females. In addition, their horns have steering and balancing function which helps while descending mountains and jumping high areas. Turs orient well and equalize their big body with the help of their symmetric horns when they relocate fast on rocky cliffs; they help them not to fall from cliffs and successfully continue moving and escaping from enemies. Caucasian turs' horns grow starting from the first year of life until 10-11 years old. Horns of males are thin and weak, not bigger than 20-25 cm and sometimes does not exist. Horns of the old turs are longer than 80 cm. Their colour is black, have a smooth surface with shallow wrinkles and furrows. The young turs have transverse tubercles on anterior surface of the horn and deep furrows between them.

The following are the morphological features of a 1,6 years old Caucasian tur: the total length is 17 cm (starting from horn basis until its tip), the girth of the fused part with frontal bones is 11 cm. These factors are significantly increasing during the 4th year of life: the total length of the horns is 49 cm and the girth of the fused part with frontal bones is 24 cm. In the 8th year of life the total length of the horns is 73 cm, the girth of the fused part with frontal bones is 32 cm. Comparative analysis of the parameters shows that the growth rate of the horn in the early years – particularly between 1.6 and 4 years was significantly higher. Apparently, this is due to the sexual maturity of males, since horns are used as the main organ in the fight during the selection of males before mating,

and between 4 and 8 years of age the growth rate of the horn decreases to 24 cm of total length, girth of the fused part with frontal bones becomes 8 cm. To conclude, during the early postnatal ontogenesis the growth rate of the horn in male is higher, it starts to decrease during the 4th year of life. The growth rate stops starting from the 8th year of life.

Observations show that, the Caucasian turs successfully move on the rocky cliffs with sharp slopes due to their large and heavy horns. At the same time, they balance their body by tilting the horns in the right direction. The level of inclination is defined by the animal itself and depends on the steepness of the slope and massiveness of the animal body. The functional significance of horns can be compared to the balancing tool of tight-rope walkers, by which, they are held and move on ropes. The difference lies in the fact that tight-rope walkers hold this tool in their hands and bend left and right to balance their body, while Caucasian turs, holding the horns on their heads and bending them in different directions balance the body and successfully adapt to high mountainous landscapes. The shape and size of turs' horns differ from each other which could be considered as a basis to assume that the shape and structure of the horns is one of the main morphological criteria for determining the species belonging (Figure 1).



Figure 1. The head of the 8 years old Caucasian tur – *C. Caucasia*



Figure 2. The structure of Caucasian tur's horn (8 years old). 1- the basis of the horn (fissure with frontal bone), 2- the body of the horn, 3- annuli ring, 4- horn tip

Anatomical-morphological studies state that the horns of the Caucasian tur - cornu, are located on the horny outgrowth of the frontal bones and covered with a horn capsule formed by the epidermis of the horn. The basis of the skin of the horn - corium cornus (dermis) is located under the epidermis with reddish papules filled with proliferation of blood vessels. Papules - papillae coriales, create a surface for feeding the producing layer of the epidermis, which forms the horn capsule. The horn consists of an apex – apexcornus, the body of the horn - corpus cornus, the base of the horn - basis cornus and the wax – epiceras.

At the base of the horn (Figure 2; 1) the wax passes into the skin. The tip of the horn has only a horny layer, therefore it can be cut painlessly without bleeding. In the area of the body of the horn under the horn capsule (Figure 2; 2) are the basal layer of the epidermis and the skin base, fused with the periosteum of the horny outgrowth of the frontal bone. Cavity inside the bone outgrowth is covered with a mucous membrane, which communicates with the sinus cavity of the frontal bone, therefore they are called the polororogium.

Only under the dermis of the wax (border) of the horn lies the subcutaneous layer of loose connective tissue. An adult Caucasian tur has multiple rings in the horn, which are of different size. Some of them are significantly different from the others with the depth and width of the lines. The lines between the rings associate with the age of the tur, thus is called an annuli ring (Figure 2;3).

Horns of turs start to grow from the first days of life until 10-11 years. Horns of females are thin and weak, rarely longer than 20-25 cm, occasionally they do not exist. The horns of the old goats, measured along the front surface, exceed 80 cm in length. They are black, have a smooth surface with shallow wrinkles and furrows. On the anterior surface of the horns of the younger goats transverse tubercles, and deep furrows between them are clearly visible.

The most interesting characteristic in the functional morphology of Caucasian tur is the shape and structure of the hoof and their prints (Figure 2) which was poorly studied in animals adapted to high-mountain habitats. Young and adult male and female animals have similar hoof shapes; the front part of the left hoof is relatively sharp, its left part somewhat longer than the right part. A cross section is observed in both of the hooves. However, the morphometric parameters of the hoof at the ages studied show the degree of adaptation to mountainous environment, and show the presence of morphological-functional differences between turs at different ages.

In order to find out the role of the hooves in adapting to high mountains, we conducted analysis of various parameters of the hoof. The results show that the length of the hoof is 3,8 cm, height is 1,9 cm and inner depth is 0,7 cm at the age of 1,6 years old. These indicators are as following at the age of 4: 4,7; 3,2; 2,6; 1,4 cm, and at the age of 8: 5,3; 3,9; 3,1 и 1,9 cm. consequently, after the birth the hooves grow very fast, which is due to the fact that the cells of the different skin layers are divided intensively. During the next stages of growth (4-8 years) the growth rate of the hooves decrease and towards the 8th year of life formation of the hoof ends.

Caucasian turs are phalanx walking (sometimes called finger-walking) animals. In autopodium (the third link of the forelimbs is called a brush), organs called hoofs and crumbs are developed from the skin. They perform supporting, protective and shock-absorbing functions as the result of various injuries. These organs are formed from the main layers of the skin. Subcutaneous layer of the skin helps to form digital cushions, which forms pillows from loose and fatty tissues. They have wrists, metacarpus and finger areas. Ungulate animals, including the Caucasian tur, have only modified digital cushion (Figure 3, 1), which have become shock absorbers for hoof horn capsules. Ahead of the cushions on the distal parts of the limbs are hooves, on which the limbs lean. The research shows that the back side of the hoof of a newborn Caucasian tur is flat. As the time moves, division is formed at the back, as well as, in front side of the hoof.

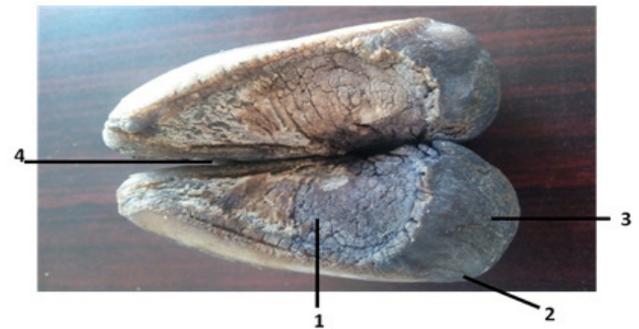


Figure 3. Lower part of the hoof 1- torusungulae 2-plantar edge3-torus digitalis4-hoof crack

Hooves-unguicula of Caucasian tur are located in the area of the third phalanx of the third and fourth fingers and four zones are distinguished in them: the rim (2), the corolla (3), the wall (4) and the sole (5).



1-rudiments of the second 2- fifth toes, 3-the wall, 4-torus, 5-hoof crack 6-the sole

Figure 4. Hooves of the front and rear limbs of Caucasian tur

1. Rim-limbus has all the three layers of skin: the epidermis, the skin and the subcutaneous layer are located on the border with the hairy skin. The rim produces a colorless horny substance-glaze, and gives the hoof shine (especially in young kids).

2. Corolla-corona, located below the rim by wide ridges. The corolla has long papillae on which the producing layer of the epidermis is located, producing a solid pigmented tubular horn. Later this horn grows downward, covering the underlying part of the hoof, on which the animal leans.

3. The wall-paries, located below the corolla fused with its periosteum, has two layers of skin (no subcutaneous layer). This structure gives it power and immobility.

4. The sole-solla. Like the wall of the hoof, it does not have a subcutaneous layer, and its epidermis grows to the plantar surface of the claw bone. The papillae of the subepidermal subcoat of the skin base are low, producing layer of the epidermis of the sole produces a soft, easily knifed plantar horn.

It is noteworthy that during the movement, the prints from the traces of the hooves of the Caucasian tur are different and this, in our opinion, is due to the contact of individual fingers with the ground, especially with rocks. It is possible to say with great probability that when traveling on rocks a large load falls on the inner finger, therefore in adult individuals the cross section is erased earlier at the right claw than at the left one. (Figure 5).

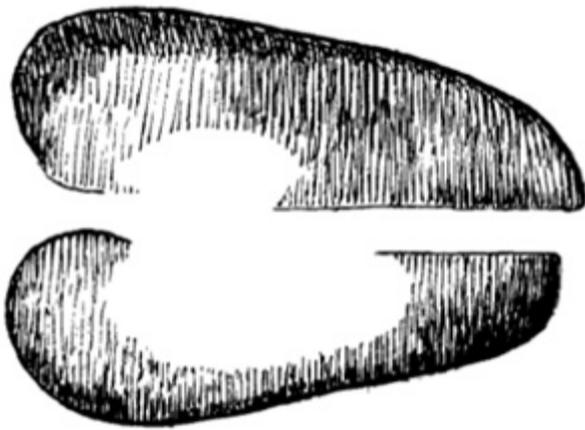


Figure 5. Tracks of hooves of the Caucasian tur

Two rudimentary toes of the anterior and posterior extremities play an important role, especially when descending from the mountains for safe and successful movement through rocky areas. These rudiments of the second and fifth fingers, located at the top of the hooves from the rear of the limbs on one side, give shock to the body, on the other hand, they participate in holding on the stones.

In recent years, scientists have suggested different opinions about the use of the Caucasian tur in genetic selection studies. For example: in the work of [5,15], experiments were conducted on domestication and crossing of turs with domestic goats. In addition, the characteristics of some biological and morphometric indicators of the West Caucasian tur are considered. It turned out that the resulting hybrid offspring are very early growing, females give up to 2 liters of milk per day.

Winter is a difficult time for turs: they suffer from a lack of food and from snow avalanches. In winter, usually during movements, males rise high, and females keep

lower, so during snow avalanches, mainly females suffer. In our opinion, snow avalanches are one of the reasons for the death of these animals.

4. Conclusion

The research has shown that the Caucasian turs are endemics Caucasus. They are adapted to severe conditions and endure freezing weather, blizzards, and sleet. Caucasian turs have a sharp eyesight, sensitive hearing and delicate sense. Their horns and hooves play the main role in adjusting to high altitudes thanks to functional morphology gained through the historical development. The horns regulate the body balance, help the animals to escape the enemies and falling. Additionally, they migrate in accordance with seasonal changes, find food and perform different biological, physiological functions.

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