# CORRELATION BETWEEN SKULL SIZE AND AGE IN HUNGARIAN GREY CATTLE

## A MAGYAR SZÜRKE MARHA KOPONYAMÉRETEK ÉS AZ ÉLETKOR KÖZÖTTI KORRELÁCIÓ

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### Abstract

*Relationships between age and certain cranial measurements were studied on 108 skulls of Hungarian Grey cattle kept in the Osteological Collection of the Hungarian Agricultural Museum. These skulls originated from individuals of 2 to 16 years of age. The cranial measurements were plotted in diagrams and the character of their relationship to age was studied using linear regression equations. The correlation factor shows a close link between the change of size and the progress of age. In the case of 20 measurement age-dependent increase could be observed, while a decrease occurred only in 3 measurements. Twenty-four measurements were independent of the individuals' age. In case of 14 sizes the correlation is medium, in case of 8 sizes the correlation is closer than medium and in case of 2 sizes the correlation is very close. In general, the widths and lengths of the skull, the frontal bone and the facial cranium vary with age. Among length values the basal size of the cerebral cranium grows to a lesser extent, while the width dimensions change more significantly as age progresses. The total length of the upper cheektooth row [P1-3+M1-3 (measurement 20)], the molar row [M1-3 (measurement 21)] and the upper premolar row [P1-3 (measurement 22)] tend to decrease with age due to intradental erosion. The length and the basis circumference of the horn cores might be expected to grow with age. The length of the horn (47a) grows 10 mm, the circuit of the horn core base (44) grows 4,22 mm annually. Bartosiewicz observed in his studies annual growth of 18 mm in cows, and that of 38 mm in oxen (Bartosiewicz 2005. 310.) Other horn core and horn measurements hardly show any increase. It seems that inheritance plays a role not only in the shape of horns but also in the length of both the horn core and the horn sheath. Horn size is also influenced by the age of castration in oxen. The basal length [St-B (14)] of the neurocranium has an interesting picture. The data of dimensions form two distinct groups, which may represent two different types of skull. The difference between the two size range is higher than 50 mm. Skulls with longer basal neurocraniums are more common.*

### Kivonat

*A koponyacsontok méretének nagysága és az életkor kapcsolatát a Magyar Mezőgazdasági Múzeum magyar szürkemarha-gyűjteményének 108 koponyáján vizsgáltam. A koponyák 2-16 éves állatoktól származtak. A koponyaméreteket diagramon ábrázoltam, és linearis regresszió függvénnyel ellenőriztem a kapcsolat jellegét. A korrelációs együttható megadta a méret és az életkor kapcsolatának szorosságát. Általánosságban elmondható, hogy 20 méret esetében a méret növekedése, 3 méretnél a csökkenése állapítható meg. 24 koponyaméret független az életkortól. Ez alapján 14 méretnél közepesnek, 8 méretnél a közepesnél szorosabbnak és 2 méretnél szorosnak nevezhető a korreláció. A koponya, a homlokcsont, valamint az arckoponya szélességi és hosszúsági méretei, általában az életkorral párhuzamosan változnak. A hosszúság méretek közül az agykoponya basalis mérete kisebb mértékben, a szélességi méretek az életkor előrehaladásával jelentősen változnak. A teljes fogsor [P1-3+M1-3 (20)], a zápfogsor [M1-3 (21)] és a premolaris fogsor [P1-3 (22)] hossza az életkor növekedésével csökken, ami a fogak intradentalis csiszolódásával magyarázható. A vizsgálatok azt mutatják, hogy a tülök hosszmérete és a szarvcsap tövének körmérete növekszik az öregedéssel párhuzamosan. A szarv (tülök) hossza (47a) 10 mm-t, a szarvcsaptő körmérete (44) 4,22 mm-t növekszik évente. Bartosiewicz László vizsgálataiban teheneknél évenként 18 mm ökröknél 38 mm növekedést állapított meg (Bartosiewicz 2005. 310.) A többi szarvval és szarvcsappal kapcsolatos méret növekedése nem függ az életkortól. Véleményem szerint az öröklött tulajdonságok nemcsak a szarv alakjában, hanem a szarvcsap és a szarv hosszában is, döntő szerepet játszanak. Jelentős hatással van a szarv méreteire, hogy a borjút hány éves korában ivartalanították. Ugyancsak érdekes jelenség, hogy az agykoponya basalis hosszának méretei [B-St (14)] alapján két jól elkülönülő csoportot alkotnak, ami két különböző koponyatípust jelenthet. A két mérettartomány közötti különbség 50 mm feletti. A hosszabb basalis agykoponyák a gyakoribbak.*


KEYWORDS: HUNGARIAN GREY CATTLE, CRANIAL MEASUREMENTS, LINEAR REGRESSION FUNCTION

KULCSSZAVAK: MAGYAR SZÜRKE MARHA, KOPONYAMÉRET, LINEÁRIS REGRESSZIÓS FÜGGVÉNY

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## Introduction

Studies of osteology and archaeozoology nowadays often raise the question that how accurately can be estimated the age (and if possible) the gender of the animal based on the size of certain parts of the skeleton and the extent of ossification. My study revolves around the skull bones of the Hungarian Grey cattle, because studies regarding the bones of the extremities have been carried out by János Matolcsi (Matolcsi 1967a,b,c., 1969, 1970, Bökönyi et al 1964). Aside from the archezoological benefits of the following examinations, the reader may expand his/her knowledge regarding the domestic animal, which played a key role in the economic history of Hungarians and is still considered to be important nowadays: the Hungarian Grey cattle.

## Material

I used the collection of Hungarian Grey cattle skulls of the Museum of Hungarian Agriculture. The majority of the available skulls is well documented including the age of the animal in many cases, thus providing great material for research. The study material contains the skulls of 5 bulls (**Fig. 1.**), 25 oxen (**Fig. 2.**) and 46 cows (**Fig. 3.**), and the skullcaps of 5 oxen and 27 cows respectively. In some cases the skull has not been preserved. In many cases the facial cranium and basal part of the cerebral cranium has been split from the frontal bone including the horn base. I call these parts of the skull with horn bases on it skullcap. The skulls obtained from animals of different age (2-16 years) (**Table 1**).

## Aims and objectives of the study

I was looking for the answers for two principal questions in my research:

Do skull dimensions vary by increasing age?

If yes, which dimensions and in what direction change over time?

## Methods

For performing the study I utilized the skull measures acquired by a measurement method internationally used in both archezoology and zoology, which was elaborated by J. U. Duerst (1930) and was simplified and revised by A. von den Driesch (1976) After the names of the dimensions, the Driesch number is found in parentheses.

I measured all the skulls for the study using the Duerst and Driesch method completed with my own measures (Kőrösi 2008 49-53 measures.). Average and limit was calculated using the 58 dimension values obtained in such a manner - grouped by gender (**Table 1**).

**Fig.1.:** Skull of bull - Hungarian Grey cattle

**1. ábra:** Magyar szürke bika koponyája

**Fig. 2.:** Skull of ox - Hungarian Grey cattle

**2. ábra:** Magyar szürke ökör koponyája

**Fig. 3.:** Skull of cow - Hungarian Grey cattle

**3. ábra:** Magyar szürke tehén koponyája

Furthermore, I determined the estimated age of skulls according to the extent of teeth change, tooth wear and suture ossification.

**Table 1.:** Limit and average values of skull dimensions in Hungarian Grey cattle - divided by gender

**1. táblázat:** A magyar szürke marha koponyák méreteinek szélső és átlagértékei nemenkénti csoportosításban

| Skull measurement | Bulls | | | Cows | | | Oxen | | |
|---|---|---|---|---|---|---|---|---|---|
| | pieces | average | end values | pieces | average | end values | pieces | average | end values |
| The greatest total length [A-P (1)] | 4 | 516.9 | 462.2-541.0 | 47 | 495.1 | 454.1-555.9 | 24 | 542.8 | 462.1-579.5 |
| Greatest condylobasal length [c-P (2)] | 4 | 495.0 | 455.8-515.2 | 47 | 477.7 | 446.5-524.5 | 24 | 516.7 | 451.5-547.5 |
| Greatest basal length [B-P (3)] | 4 | 466.6 | 421.0-483.5 | 46 | 447.2 | 415-490.0 | 23 | 486.5 | 459.6-518.8 |
| Greatest neurocranium length [B-N (6)] | 4 | 257.5 | 240.0-270.0 | 35 | 243.1 | 218.6-270.0 | 13 | 260.0 | 240.0-280.0 |
| Viscerocranium length (7) | 4 | 273.3 | 242.3-290.8 | 47 | 260.1 | 206.2-300.1 | 24 | 290.2 | 248.4-311.6 |
| The median frontal length [A-N (8)] | 4 | 247.0 | 226.0-268.5 | 49 | 235.9 | 203.4-271.2 | 24 | 259.1 | 216.7-280.5 |
| Short upper cranium length [A-Rh (10)] | 4 | 440.1 | 390.2-458.7 | 45 | 405.9 | 375.9-436.4 | 22 | 443.3 | 394.0-483.4 |
| Greatest length of the nasals [N-Rh (12)] | 4 | 193.8 | 167.6-213.4 | 45 | 168.7 | 137.8-191.6 | 22 | 186.0 | 164.4-212.2 |
| Basal length of the neurocranium [B-St (14)] | 4 | 232.2 | 188.5-274.0 | 45 | 224.9 | 158.7-270.5 | 23 | 245.2 | 185.6-280.9 |
| The lateral length of the muzzle [If-P (16)] | 4 | 161.4 | 143.2-173.0 | 45 | 152.0 | 135.1-168.6 | 24 | 163.1 | 142.8-181.3 |
| Dental length of the palate [P-Pd (17)] | 4 | 273.9 | 269.4-276.4 | 46 | 265.7 | 245.8-281.7 | 24 | 273.9 | 226.6-289.5 |
| Medial length of the palate [P-St (17a)] | 4 | 279.2 | 253.2-298.8 | 47 | 276.1 | 257.7-298.0 | 24 | 297.1 | 251.3-316.3 |
| Greatest oral palatal length [P-Po (18)] | 4 | 207.3 | 185.1-216.9 | 47 | 201.5 | 182.0-218.7 | 24 | 216.0 | 183.5-238.4 |
| Medial length of the palatine bone [Po-St (18a)] | 4 | 75.3 | 68.1-81.0 | 47 | 75.5 | 64.1-84.9 | 24 | 82.3 | 67.2-96.0 |
| Lateral length of the premaxilla [Ni - P (19)] | 4 | 178.0 | 164.3-201.4 | 47 | 160.9 | 118.6-195.6 | 24 | 171.0 | 145.7-223.0 |
| Length of the cheektooth row [$P^1$-$M^3$ (20)] | 4 | 126.4 | 118.8-141.5 | 47 | 128.3 | 112.4-141.7 | 24 | 132.7 | 121.4-149.7 |
| Length of the molar row [$M^{1-3}$ (21)] | 4 | 78.0 | 73.0-86.6 | 47 | 78.5 | 56.1-86.4 | 24 | 81.2 | 73.1-91.6 |
| Length of the premolar row [$P^{1-3}$ (22)] | 4 | 49.7 | 46.0-57.6 | 43 | 51.4 | 43.5-85.2 | 23 | 51.5 | 44.3-58.4 |
| Greatest inner length of the orbit [Ent-Ect (23)] | 4 | 71.3 | 64.5-73.7 | 49 | 67.0 | 57.8-73.8 | 24 | 72.8 | 61.1-87.2 |
| Greatest inner heigth of the orbit (24) | 4 | 66.1 | 63.5-68.6 | 49 | 62.9 | 57.7-69.8 | 24 | 68.7 | 62.2-74.7 |
| Greatest mastoid breadth [Ot-Ot (25)] | 4 | 271.8 | 227.3-288.6 | 47 | 223.7 | 202.3-258.6 | 24 | 251.8 | 218.8-275.0 |
| Greatest breadth of the occipital condyles (26) | 4 | 122.6 | 117.9-129.6 | 48 | 108.1 | 92.4-129.0 | 24 | 125.6 | 110.3-198.6 |
| Greatest breadth at the bases of the of the paraoccipital processes (27) | 4 | 191.9 | 169.9-206.6 | 48 | 167.6 | 147.9-186.9 | 24 | 189.1 | 113.4-221.0 |
| Greatest breadth of the foramen magnum (28) | 4 | 32.8 | 26.5-35.6 | 47 | 40.0 | 30.7-51.6 | 24 | 42.0 | 27.7-64.3 |
| Greatest height of the foramen magnum [B-O (29)] | 4 | 34.8 | 32.7-36.3 | 46 | 38.0 | 31.0-43.2 | 22 | 47.1 | 35.7-45.7 |
| Least occipital breadth [Osp-Osp (30)] | 4 | 198.2 | 180.6-214.0 | 72 | 137.9 | 113.6-173.9 | 28 | 161.0 | 117.7-198.6 |
| Least breadth between the bases of the horncores (31) | 4 | 128.4 | 115.5-141.0 | 73 | 151.3 | 106.2-199.9 | 28 | 157.5 | 125.0-192.3 |
| Least frontal breadth [fs-fs (32)] | 4 | 207.2 | 193.6-225.2 | 67 | 174.3 | 157.2-193.4 | 28 | 199.2 | 177.2-230.5 |
| Greatest frontal breadth [Ect-Ect (33)] | 4 | 259.3 | 222.4-274.5 | 49 | 222.4 | 202.5-247.2 | 27 | 244.9 | 213.7-267.4 |
| Least breadth between the orbits [Ent – Ent (34)] | 4 | 208.0 | 177.6-229.5 | 48 | 170.5 | 151.7-228.2 | 24 | 188.3 | 158.9-211.2 |

**Table 1., cont.**

**1. táblázat., folyt.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Greatest facial breadth [M-M (35)] | 4 | 171.8 | 154.2-180.0 | 45 | 156.9 | 135.2-179.3 | 24 | 169.1 | 141.8-188.5 |
| Greatest breadth across the premaxillae on the oral protuberances (37) | 4 | 103.0 | 83.4-108.4 | 44 | 88.1 | 76.2-100.7 | 24 | 98.5 | 86.3-109.8 |
| Greatest palatal breadth (38) | 4 | 145.9 | 132.4-156.2 | 47 | 136.4 | 119.9-153.2 | 24 | 143.5 | 125.0-157.9 |
| Least inner height of the temporal groove (39) | 4 | 249.7 | 213.3-262.8 | 47 | 216.4 | 198.4-245.5 | 24 | 237.1 | 207.9-257.7 |
| Greatest height of the occipital region [B-A (40)] | 4 | 170.9 | 146.5-188.6 | 46 | 154.8 | 114.0-171.2 | 23 | 168.4 | 149.3-200.5 |
| Least height of the occipital region [O-A (41)] | 4 | 129.4 | 114.3-151.2 | 47 | 120.5 | 104.7-156.7 | 21 | 127.5 | 115.8-159.7 |
| Horncore basal cirkumference (44) | 3 | 413.2 | 248.0-871.0 | 53 | 221.8 | 171.0-308.0 | 24 | 93.1 | 69.9-122.0 |
| Greatest diameter of the horncore base (45) | 4 | 101.1 | 79.7-115.3 | 56 | 68.9 | 55.4-85.2 | 23 | 292.0 | 225.0-367.0 |
| Least diameter of the horncore base (46) | 4 | 99.2 | 75.6-132.2 | 57 | 64.0 | 51.4-79.4 | 25 | 86.7 | 63.1-105.3 |
| Length of the outer curvature of the horncore (47) | 1 | 570.0 | 523.0-617.0 | 48 | 489.7 | 332.0-632.0 | 17 | 657.8 | 498.0-815.0 |
| Greatest length of the horn (47a) | 4 | 733.8 | 611.0-854.0 | 67 | 649.7 | 475.0-837.0 | 28 | 909.0 | 616.0-1359.0 |
| Oral breadth between the bases of the horncores (48) | 4 | 248.2 | 238.3-254.6 | 65 | 220.5 | 191.0-261.3 | 28 | 253.4 | 214.5-295.5 |
| Greatest breadth of collum the premaxillae (50) | 4 | 92.9 | 77.8-98.8 | 44 | 81.6 | 72.4-90.9 | 24 | 93.2 | 81.3-104.3 |

This was followed by checking the data collection pertaining skull age. Since animal gender affects certain characteristics of the skull (Kőrösi 2008), bulls and cows were accounted separately, as well as oxen, because signs of castration can be seen not only on extremity bones, but also on the cranium. Skull dimensions are represented on diagrams.

Diagrams were created in two steps. First, I used the skulls with their age indicated on the cardboards. These include the skulls of 5 bulls, 26 cows and 4 oxen (**Table 1.**). Only the cardboards of cow skulls contained sufficient information for statistical analysis, therefore the dimensions of cow skulls were examined separately compared to age. Due to the low number of bull skulls and the lack of accurate data on ox skulls these examinations have not been conducted in these categories. Results obtained on the diagram were checked by linear regression function, with the most important results integrated into a table (**Table 3**). This was followed by the age estimation of 47 cows and 21 oxen. The age of these skulls was not indicated on the cardboards (**Table 2**). Completed by the dimensions of these individuals I prepared the diagrams regarding all skulls (selection: **Figs. 4-13**), then I compared the results of the diagrams and the function. Differences of important skull dimensions, and the deviations between diagrams and statistical tests have been separately indicated in the text. If difference was found in the skull dimensions between genders, I noted this in the text.

The diagrams depict the skull dimensions of each available individual in relation to age. By this method we can pictorially represent the connection between age and dimension. Some diagrams demonstrate the values of the same skull dimension measured on differently aged animals. The acquired dot clouds infer whether age and dimension are connected.

Results based on diagrams can be well checked by using linear regression functions (SPSS). The regularity between quantitative criteria is described by regression functions. The model of linear regression is based on the assumption of linear correlation between the two variables. The correlation between age (independent variable) and dimensions (dependent variable), i.e. our hypothesis regarding the steepness of linear regression function was checked by t-test. According to our null hypothesis there is no significant correlation between the increase of age and dimensions. If the steepness does not significantly differ from 0, then our null hypothesis is accepted. If the steeepness of regression function is significantly different than 0, then our null hypothesis is rejected and the alternative hypothesis is accepted, i.e. the given skull dimension changes with varying age.

**Table 2.:** Distribution of skulls of Hungarian Grey cattle - divided by documented and estimated age

**2. táblázat:** A magyar szürke marha koponyák megoszlása adatolt és becsült életkorok alapján

| Age (years) | cows | | bulls | oxen | | all |
|---|---|---|---|---|---|---|
| | documented* | estimated | documented | documented* | estimated | |
| 2 | | | 1 | | | 1 |
| 3 | | 2 | | | | 2 |
| 3,5 | 3 | | | | 1 | 4 |
| 4 | 2 | 3 | | | | 5 |
| 5 | 3 | 2 | | | 2 | 7 |
| 6 | | 5 | | | 5 | 10 |
| 7 | 4 | 3 | | | 2 | 9 |
| 8 | | 6 | | | 1 | 7 |
| 9 | 3 | 2 | 1 | | 3 | 9 |
| 10 | 6 | 5 | 1 | 3 | 3 | 18 |
| 12 | 1 | 12 | 2 | 1 | 2 | 18 |
| 13 | | | | | 1 | 1 |
| 14 | | 6 | | | 1 | 7 |
| 14,5 | 1 | | | | | 1 |
| 15 | 2 | | | | | 2 |
| 16 | 1 | 1 | | | | 2 |
| undefinable | | | | | 5 | 5 |
| all | 26 | 47 | 5 | 4 | 21 | 108 |

*the exact age found in the inventory book and on the description card (counted on the basis of the date of birth and the time of arrival to the slaughterhouse).

If the steepness is positive, increasing age implies the growth of skull dimension. If the steepness is negative, increasing age implies the reduction of skull dimension. The significance level of 5% has been taken into account in all cases.

The correlation factor shows a close link between the change of size and the progress of age (**Table 3**.). In case of skulls where correlation is apparent between size and age, I made three groups. Medium correlation is apparent between 40 and 60%, closer than medium correlation is apparent between 61 and 80% and there is a close correlation in case of values between 81 and 100%.

## *Study results*

According to the results the skull dimensions can be divided into three groups:

1. Correlation between skull measurements and age is present:

the change can be increasing or decreasing.

2. Correlation between skull measurements and age is not present:

connection between measurement and age increase cannot be proved.

3. Correlation between the changes of measurements and age cannot be observed. The number of available skulls is insufficient in case of certain measurements, thus the examination has not been carried out.

4.1. Correlation between skull measurements and age is present.

4.1.1.Correlation between skull measurements and age increase is present, the change is of the same direction:

21 skull measurements (2, 3, 6, 10, 16, 17a, 18, 19, 25, 27, 30, 32, 33, 34, 35, 37, 38, 39, 44, 47a, 50. Kőrösi 2008. 31-32.) change over ageing according to the studies.

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**Table 3:** Change of the most important skull dimension in cows (Hungarian Grey cattle) according to linear regression function

**3. táblázat:** A szürke marha tehenek legfontosabb koponyaméretének változása az életkor függvényében a linearis regresszió függvény alapján

| **Skull measurement** | | **Unstandardized Coefficients** | | **Linear correlation** | | **Sig.** |
|---|---|---|---|---|---|---|
| **The measure grow with the age** | | **m** | **Std. Error** | **r** | **t** | **p** |
| Greatest condylobasal length [c-P (2)] | (Constant) | 458.276 | 8.212 | | 55.805 | 0.000 |
| | age | 2.274 | 0.946 | 0.504 | 2.403 | 0.028 |
| Greatest basal length [B-P (3)] | (Constant) | 427.222 | 7.690 | | 55.556 | 0.000 |
| | age | 2.467 | 0.886 | 0.560 | 2.784 | 0.013 |
| Greatest neurocranium length [B-N (6)] | (Constant) | 173.221 | 21.191 | | 8.174 | 0.000 |
| | age | 6.438 | 2.442 | 0.539 | 2.636 | 0.017 |
| Short upper cranium length [A-Rh (10)] | (Constant) | 389.345 | 7.638 | | 50.974 | 0.000 |
| | age | 2.130 | 0.814 | 0.536 | 2.619 | 0.018 |
| The lateral length of the muzzle [If-P (16)] | (Constant) | 137.885 | 3.455 | | 39.904 | 0.000 |
| | age | 1.660 | 0.369 | 0.747 | 4.494 | 0.000 |
| Medial length of the palate [P-St (17a)] | (Constant) | 264.830 | 4.723 | | 56.075 | 0.000 |
| | age | 1.540 | 0.544 | 0.566 | 2.830 | 0.012 |
| Greatest oral palatal length [P-Po (18)] | (Constant) | 184.685 | 3.467 | | 53.262 | 0.000 |
| | age | 2.086 | 0.369 | 0.808 | 5.648 | 0.000 |
| Lateral length of the premaxilla [Ni - P (19)] | (Constant) | 141.463 | 8.820 | | 16.040 | 0.000 |
| | age | 2.723 | 0.939 | 0.575 | 2.899 | 0.010 |
| Greatest mastoid breadth [Ot-Ot (25)] | (Constant) | 206.979 | 5.254 | | 39.396 | 0.000 |
| | age | 2.039 | 0.605 | 0.633 | 3.368 | 0.004 |
| Greatest breadth at the bases of the of the paraoccipital processes (27) | (Constant) | 159.308 | 4.281 | | 37.213 | 0.000 |
| | age | 1.064 | 0.453 | 0.465 | 2.347 | 0.029 |
| Least occipital breadth [Osp-Osp (30)] | (Constant) | 124.486 | 5.756 | | 21.628 | 0.000 |
| | age | 1.790 | 0.656 | 0.486 | 2.727 | 0.012 |
| Least frontal breadth [fs-fs (32)] | (Constant) | 164.533 | 4.089 | | 40.237 | 0.000 |
| | age | 1.138 | 0.439 | 0.484 | 2.591 | 0.017 |
| Greatest frontal breadth [Ect-Ect (33)] | (Constant) | 200.005 | 12.954 | | 15.440 | 0.000 |
| | age | 3.433 | 1.506 | 0.473 | 2.280 | 0.035 |
| Least breadth between the orbits [Ent – Ent (34)] | (Constant) | 153.060 | 4.022 | | 38.057 | 0.000 |
| | age | 1.787 | 0.448 | 0.717 | 3.989 | 0.001 |
| Greatest facial breadth [M-M (35)] | (Constant) | 141.090 | 4.022 | | 35.082 | 0.000 |
| | age | 1.869 | 0.428 | 0.727 | 4.363 | 0.000 |
| Greatest breadth across the premaxillae on the oral protuberances (37) | (Constant) | 144.927 | 4.820 | | 30.067 | 0.000 |
| | age | 1.541 | 0.555 | 0.558 | 2.773 | 0.013 |

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**Table 3., cont.**

**3. táblázat, folyt.**

| **Skull measurement** | | **Unstandardized Coefficients** | | **Linear correlation** | | **Sig.** |
|---|---|---|---|---|---|---|
| | | **m** | **Std. Error** | **r** | **t** | **p** |
| Greatest palatal breadth (38) | (Constant) | 123.407 | 2.175 | | 56.726 | 0.000 |
| | age | 1.526 | 0.232 | 0.848 | 6.584 | 0.000 |
| Least inner height of the temporal groove (39) | (Constant) | 203.488 | 3.371 | | 60.372 | 0.000 |
| | age | 1.384 | 0.359 | 0.683 | 3.856 | 0.001 |
| Horn core basal cirkumference (44) | (Constant) | 181.598 | 16.781 | | 10.822 | 0.000 |
| | age | 4.122 | 1.747 | 0.533 | 2.360 | 0.033 |
| Greatest length of the horn (47a) | (Constant) | 561.982 | 32.079 | | 17.519 | 0.000 |
| | age | 10.021 | 3.659 | 0.488 | 2.739 | 0.011 |
| Greatest breadth of collum the premaxillae (50) | (Constant) | 71.359 | 2.005 | | 35.590 | 0.000 |
| | age | 1.105 | 0.214 | 0.782 | 5.176 | 0.000 |
| **The measurement decreases with the growth of age** | | | | | | |
| Length of the cheektooth row [$P^1$-$M^3$ (20)] | (Constant) | 138.969 | 3.213 | | 43.259 | 0.000 |
| | age | -1.440 | 0.370 | -0.686 | -3.888 | 0.001 |
| Length of the molar row [$M^{1-3}$ (21)] | (Constant) | 82.288 | 1.912 | | 43.035 | 0.000 |
| | age | -0.493 | 0.220 | -0.477 | -2.238 | 0.039 |
| Length of the premolar row [$P^{1-3}$ (22)] | (Constant) | 57.391 | 1.617 | | 35.502 | 0.000 |
| | age | -0.865 | 0.186 | -0.748 | -4.641 | 0.000 |
| **No correlation between mesaurements and the growth of age** | | | | | | |
| Greatest total length [A-P (1)] | (Constant) | 478.421 | 9.758 | | 49.030 | 0.000 |
| (1-16 years old cows) | age | 2.122 | 1.125 | 0.416 | 1.887 | 0.076 |
| Greatest total length [A-P (1)] | (Constant) | 481.640 | 12.556 | | 38.359 | 0.000 |
| (1-10 years old cows) | age | 2.022 | 1.792 | 0.272 | 1.129 | 0.276 |
| Viscerocranium length (7) | (Constant) | 244.471 | 14.002 | | 17.460 | 0.000 |
| Nasion (N) in medium position | age | 1.486 | 1.383 | 0.308 | 1.074 | 0.306 |
| Viscerocranium length (7) | (Constant) | 243.703 | 9.662 | | 25.222 | 0.000 |
| Nasion (N) in aboral position | age | 2.921 | 1.495 | 0.699 | 1.954 | 0.122 |
| Median frontal length [A-N (8)] | (Constant) | 224.933 | 9.280 | | 24.237 | 0.000 |
| All included | age | 1.618 | 0.988 | 0.369 | 1.637 | 0.120 |
| Median frontal length [A-N (8)] | (Constant) | 231.129 | 10.920 | | 21.165 | 0.000 |

**Table 3., cont.**

**3. táblázat, folyt.**

| **Skull measurement** | | **Unstandardized Coefficients** | | **Linear correlation** | | **Sig.** |
|---|---|---|---|---|---|---|
| | | **m** | **Std. Error** | **r** | **t** | **p** |
| Nasion (N) in medium position | age | 1.008 | 1.079 | 0.271 | 0.935 | 0.370 |
| Median frontal length [A-N (8)] | (Constant) | 221.610 | 12.609 | | 17.575 | 0.000 |
| Nasion (N) in aboral position | age | 0.852 | 1.950 | 0.213 | 0.437 | 0.685 |
| Greatest length of the nasals [N-Rh (12)] | (Constant) | 160.315 | 6.907 | | 23.211 | 0.000 |
| All included | age | 0.788 | 0.736 | 0.251 | 1.071 | 0.299 |
| Greatest length of the nasals [N-Rh (12)] | (Constant) | 168.764 | 4.445 | | 37.965 | 0.000 |
| Medium nasals | age | 0.679 | 0.596 | 0.339 | 1.140 | 0.281 |
| Greatest length of the nasals [N-Rh (12)] | (Constant) | 150.116 | 6.933 | | 21.652 | 0.000 |
| Short nasals | age | 0.734 | 0.617 | 0.470 | 1.190 | 0.288 |
| Basal length of the neurocranium [B-St (14)] | (Constant) | 196.573 | 24.269 | | 8.100 | 0.000 |
| | age | 3.218 | 2.585 | 0.289 | 1.245 | 0.230 |
| Dental length of the palate [P-Pd (17)] | (Constant) | 262.941 | 2.988 | | 87.997 | 0.000 |
| | age | 0.380 | 0.318 | 0.278 | 1.194 | 0.249 |
| Medial length of the palatine bone [Po-St (18a)] | (Constant) | 90.332 | 13.588 | | 6.648 | 0.000 |
| | age | -1.152 | 1.438 | -0.176 | -0.801 | 0.432 |
| Greatest inner length of the orbit [Ent-Ect (23)] | (Constant) | 66.505 | 1.797 | | 37.001 | 0.000 |
| | age | -0.026 | 0.194 | -0.032 | -0.135 | 0.894 |
| Greatest inner heigth of the orbit (24) | (Constant) | 61.201 | 1.812 | | 33.775 | 0.000 |
| | age | 0.243 | 0.195 | 0.281 | 1.244 | 0.229 |
| Greatest breadth of the occipital condyles (26) | (Constant) | 158.858 | 4.894 | | 32.458 | 0.000 |
| | age | 1.155 | 0.564 | 0.445 | 2.048 | 0.056 |
| Greatest breadth of the foramen magnum (28) | (Constant) | 40.850 | 2.821 | | 14.482 | 0.000 |
| | age | -0.046 | 0.300 | -0.037 | -0.152 | 0.881 |
| Greatest height of the foramen magnum [B-O (29)] | (Constant) | 36.704 | 1.806 | | 20.324 | 0.000 |
| | age | 0.180 | 0.192 | 0.222 | 0.938 | 0.361 |

**Table 3., cont.**

**3. táblázat, folyt.**

| Skull measurement | | Unstandardized Coefficients | | Linear correlation | | Sig. |
|---|---|---|---|---|---|---|
| | | m | Std. Error | r | t | p |
| Least breadth between the bases of the horn cores (31) | (Constant) | 145.981 | 7.520 | | 19.412 | 0.000 |
| | age | 0.852 | 0.810 | 0.210 | 1.052 | 0.303 |
| Greatest height of the occipital region [B-A (40)] | (Constant) | 146.600 | 6.531 | | 22.448 | 0.000 |
| | age | 1.009 | 0.696 | 0.332 | 1.450 | 0.165 |
| Least height of the occipital region [O-A (41)] | (Constant) | 121.921 | 5.938 | | 20.533 | 0.000 |
| | age | -0.090 | 0.618 | -0.036 | -0.145 | 0.887 |
| Greatest diameter of the horn core base (45) | (Constant) | 62.338 | 3.668 | | 16.997 | 0.000 |
| | age | 0.847 | 0.418 | 0.477 | 2.028 | 0.062 |
| Least diameter of the horn core base (46) | (Constant) | 60.982 | 3.922 | | 15.549 | 0.000 |
| | age | 0.320 | 0.428 | 0.184 | 0.748 | 0.465 |
| Length of the outer curvature of the horn core (47) | (Constant) | 467.966 | 31.077 | | 15.058 | 0.000 |
| | age | 1.276 | 3.505 | 0.100 | 0.364 | 0.722 |
| Oral breadth between the bases of the horn cores (48) | (Constant) | 216.046 | 4.845 | | 44.592 | 0.000 |
| | age | 0.472 | 0.522 | 0.182 | 0.905 | 0.375 |

Cranial lengths with different increase rate can be observed.

The combined length of the frontal bone and nasal bone [A-Rh (10)] is growing over ageing (**Table 3.**). This growth in case of cows is approx. 2.13 mm per year.

Condylobasal [c-P (2)] and basal [B-P (3)] lengths of the skull base reveal slight increase of basal length, which is verified by the linear regression function (**Table 3.**). The growth is more than 2 mm per year in case of both measurements. It can be stated that cranial lengths grow gradually by ageing.

Widths of the frontal bone vary in different ways.

The “slenderness”, i.e. the least breadth [fs-fs (32)] of the frontal bone, the greatest breadth [Ect-Ect (33)] of the frontal bone and the distance between the orbits [Ent-Ent (34)] display increase. These results have been verified by statistical tests (**Table 3**.). The first two measurements grow in case of cows 1.1-1.5 mm per year, however, the distance between the eyes revealed a more remarkable increase of 3.43 mm. It can be stated that the frontal bone gets more wide by ageing. The distance between the two zygomatic archs [Zy-Zy (39)] also widens, in cows 1.384 mm per year.

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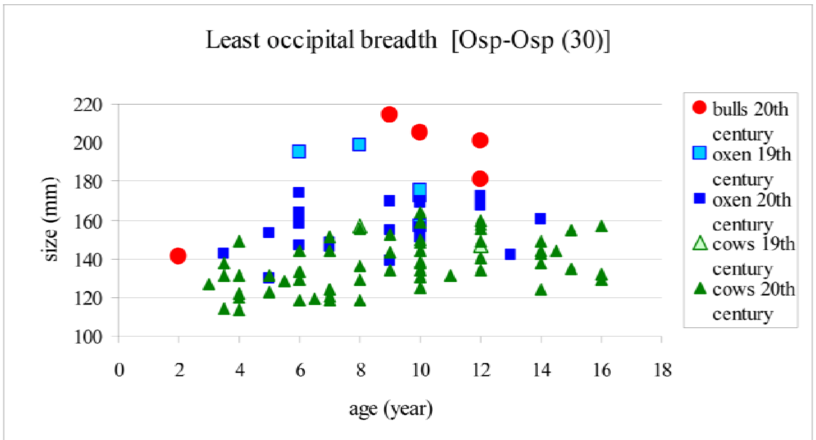


**Fig. 4.:** Least occipital breadth in skulls of Hungarian Grey cattles

**4. ábra:** A szürkemarha-koponyák nyakszirti régiójának legkisebb szélessége

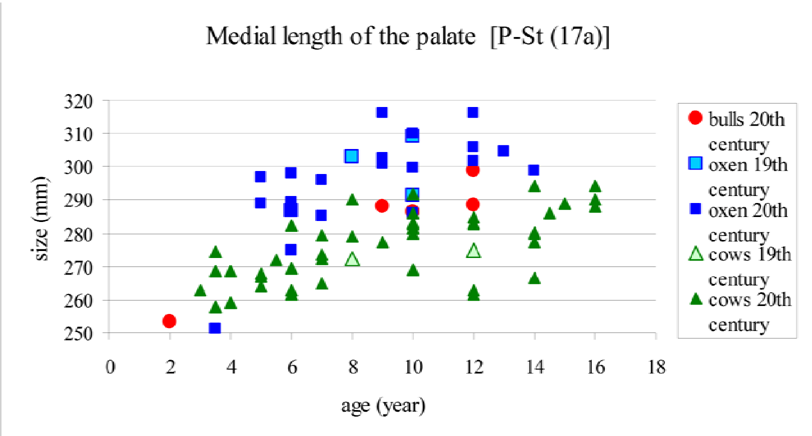


**Fig. 5.:** Medial length of the palate in skulls of Hungarian Grey cattles

**5. ábra:** A szürkemarha-koponyák medialis szájpadláshossza

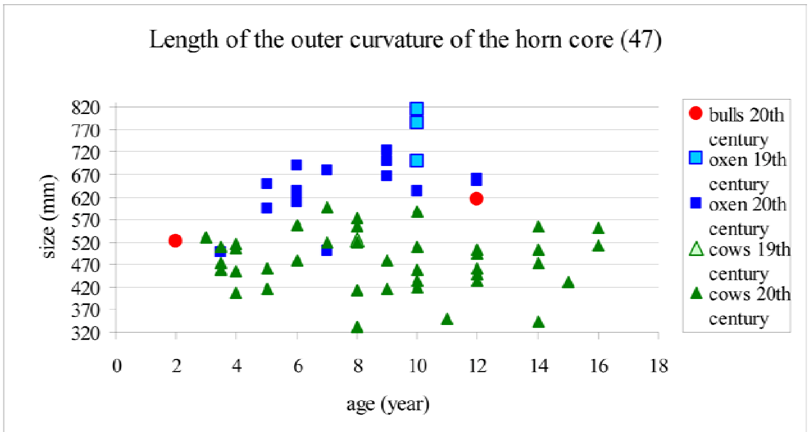


**Fig. 6.:** Length of the outer curvature of the horn core in Hungarian Grey cattles

**6. ábra:** A szürkemarha-szarvcsapok legnagyobb hossza

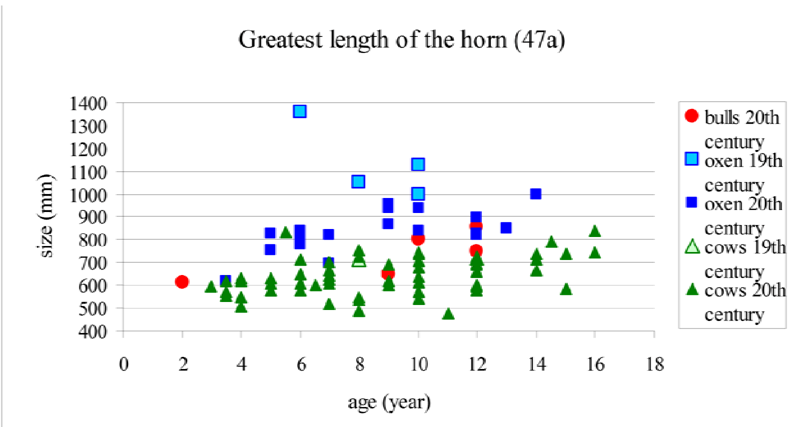


**Fig. 7.:** Greatest length of the horn in Hungarian Grey cattles

**7. ábra:** A szürkemarha-koponyák szarvának legnagyobb hossza

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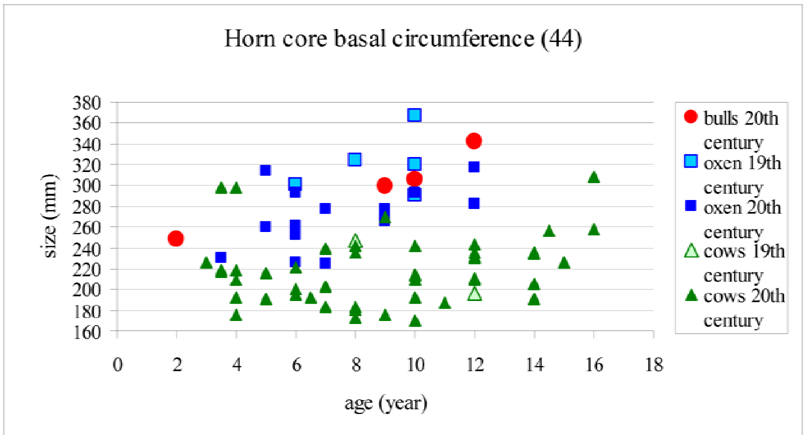


**Fig. 8.:** Horn core basal cirkumference in skulls of Hungarian Grey cattles

**8. ábra:** A szürkemarha-koponyák szarvcsaptövének körmérete

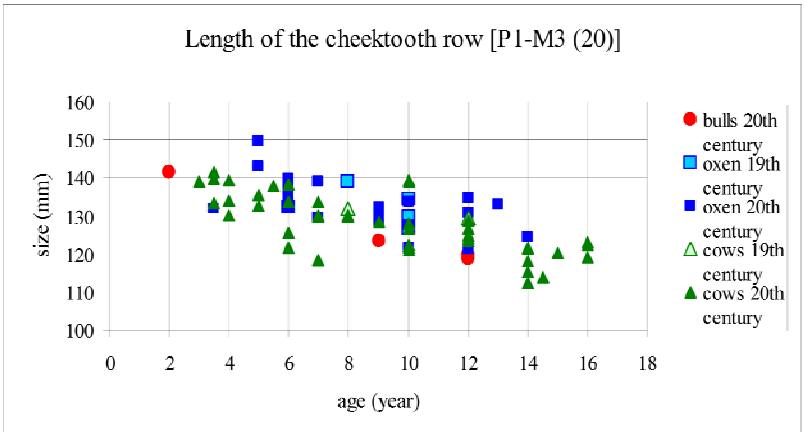


**Fig. 9.:** Length of the cheektooth row in skulls of Hungarian Grey cattles

**9. ábra:** A szürkemarha-koponyák zápfogsorának hossza

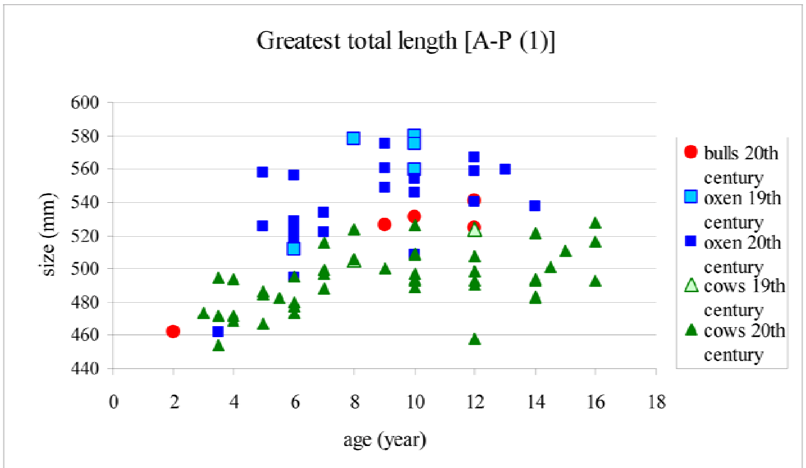


**Fig. 10.:** Greatest total length of Hungarian Grey cattles

**10. ábra:** A szürkemarha-koponyák frontalis hossza

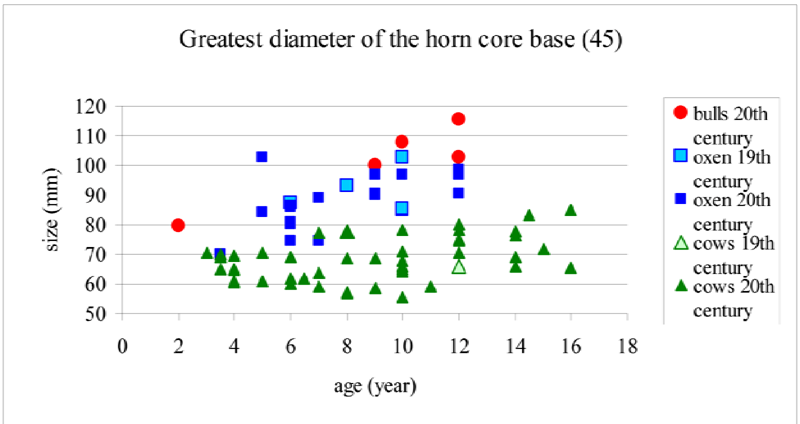


**Fig. 11.:** Greatest diameter of the horn core base in skulls of Hungarian Grey cattles

**11. ábra:** A szürkemarha-koponyák szarvcsaptövének szélessége

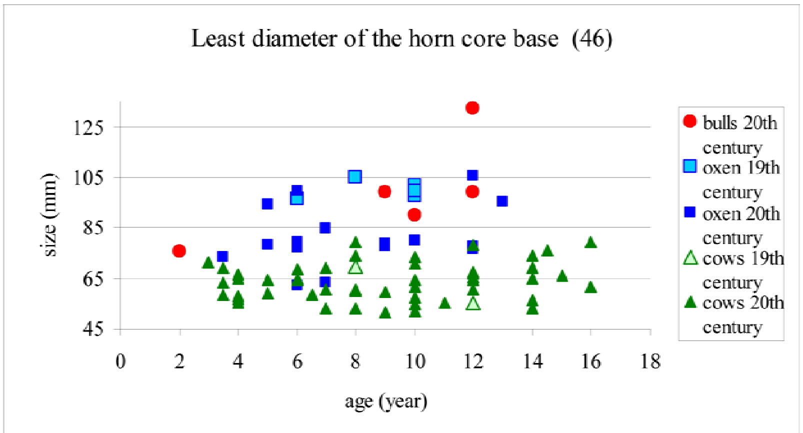


**Fig. 12.:** Least diameter of the horn core base in skulls of Hungarian Grey cattles

**12. ábra:** A szürkemarha-koponyák szarvcasptövének magassága

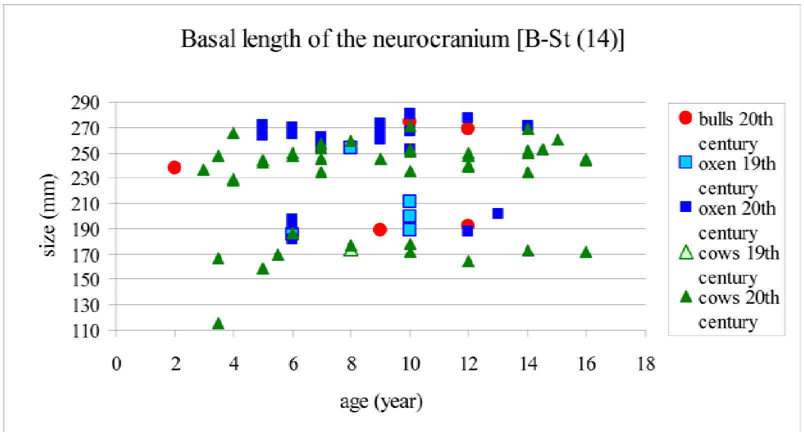


**Fig. 13.:** Basal length of the neurocranium of Hungarian Grey cattles

**13. ábra:** A szürkemarha-agykoponyák basalis hossza

The rates of the facial cranium vary differently as well.

The lateral length of the muzzle [If-P (16)] on the facial part of the skull grows gradually with age. Within cows of the same age the values may vary over a wide range.

The greatest breadth of the facial cranium [M-M (35)] grows with age. This growth can be only partially attributed to the widening of jawbones, it is in part caused by the gradual protrusion of the tuber malare (M). Its annual growth in cows is 1.87 mm. Similar width growth can be observed in the greatest breadth of the premaxillae (incisive bones) (37). Along with this the collum of premaxillary bones also gets wider (50).

The nasal process of the premaxillary bone (nasal process of the incisive bone) [P-Ni (19)] can be short, medium or long. The measurement can be performed only on skulls with medium nasal process (51 pcs – 67,5 %), the nasal process grows with age. This growth is remarkable with 2.72 mm per year in cows.

In case of short nasal process the intermaxillary bone does not reach the nasal bone, therefore nasointermaxillary (Ni) and nasoliberal (Nl) points are not present on the skull. Therefore in skulls with short nasal process the dimensions 19, 51, és 52 cannot be measured. If the nasal process is long, it reaches the lacrimal bone. In this case nasointermaxillary (Ni) point is not formed, it is located in the of the lacrimomaxillary oral/nasomaxillary (Lmo/Nm) spots. In this case dimensions No. 52 and 53 cannot be measured.

This change can also be observed in the bones of the nuchal part of the neurocranium. The breadth of the occipital region [Ot-Ot (25)] and jugular processes (27) slightly grows with age. The first dimension grow more then 2 mm, the second one grow only 1.064 mm per year in cows (**Table 3.**).

During the examination of different skulls it appeared presumable that the shortest breadth of the occipital region (temporal fossa) [Osp-Osp (30)] widens with age (**Table 1.**). The temporal fossa of cow skulls with known age is widening until the age of 10 – then the reached size becomes permanent. Cows with estimated age showed the slow growth of the dimension (1.79 mm per year), whereas no correlation has been revealed regarding oxen, and decrease of the dimension could be observed on bulls. The latter is presumably attributed to individual characteristics, leaving no place for generalization. The linear regression function revealed growth of the dimension with age, i.e. the decrease of slenderness.

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Changes in the widths and lengths of the palate vary. The greatest breadth of the palate (38) grows slightly. In case of individuals both with known and estimated age an increase could be scrutinized in the medial length of the palate [P-St (17a)] (**Table 2.**). The combined length of the palatine process of maxilla and the premaxillary bone [P-Po (18)] exhibited significant growth substantiated by statistical tests. The dental length of the palate [P-Pd (17)] and the medial length of the palatine bone [Po-St (18a) vary independently (see 4.2).

The length and width growth of the horn base and horn is presumed with age. However, the measurements of the horn base and horn are different than expected (see 4.3 for details). The length of horn/horn base and the diameter of horn base radix display controversial results. No growth can be observed in the length of horn core base (47) (**Fig. 6.**), but the horn length (47a) grows remarkably with age (**Fig. 7.**). Bartosiewicz examined the horn growth of 24 cows and 15 oxen. In his studies he observed annual growth of 18 mm in cows, and that of 38 mm in oxen (Bartosiewicz 2005. 310.). In my present research an annual growth of 10 mm has been revealed (**Table 3.**).

Unequivocal growth can be observed at the circumference of the horn core base radix (44) in bulls (**Fig. 8**.), which is caused by forceful bone deposition on different parts – including the horn base – of the bull skull, called horn rose. This growth is safe to say in spite of little data. In my opinion the growth of the horn base radix is stopped after reaching a certain age according to observations performed on other parts of the skull. In case of a larger number of bull skulls it would be recommended to find out the duration of this ossification and the moment when the thickening stops. No unequivocal growth of circumference of horn base radix is revealed by the diagram in cows and oxen. However, in my opinion in elderly age (approx. after 12 years) with the progression of ossification it may show slight growth. The growth of circumference of horn base radix is also confirmed by regression function, though independence has been revealed in the case of width and thickness of horn radix (**Table 3**.). The change of three measurements correlate with each other, thus this statistical result can only be accepted with doubts. It may be verified or confuted by studies performed with more data. The dimensions of the horn base radix is connected with genetics, what may also affect the results.

In case of the examined sizes the linear regression functions give the approximate annual growth of the size. Based on this the greatest growth is observed at the longest size of the horn, horn core and the greatest length of the neurocranium [B-N (6)]. The length of the horn (47a) grows 10 mm, the circuit of the horn core base (44) grows 4,22 mm annually.

4.1.2 Correlation between skull measurement and age increase is present, but the change is of different directions:

Three lengths (20, 21, 22, Kőrösi 2008) of the facial cranium decrease with age.

The most interesting change is found in the length of the cheecktooth row [P1-M3 (20)] and in the length of premolar [P1-3 (22)] and molar [M1-3] (21)] dentures. All of these denture sizes decrease a great deal by ageing (**Fig. 9.**). The scale of decrease is the highest in the length of the premolar [P1-3 (22)]. The statistical tests of these three dentures revealed the decrease of sizes with age, with a value of 0,5-1,4 mm in the case of cows (**Table 3**.). C. Grigson also reported the decrease of denture lengths in his reaserch, explained by the intradental grinding of molars leading to thinning from the crown in the direction of the root (Grigson 1974). As a result of the horizontal abrasion of the occlusal surface of the palm that is narrowing towards the root of the tooth the neighboring teeth are drawing closer to each other. That is the reason for shortening.

4.2 No correlation between age and size.

24 skull measurements (1, 8, 11, 12, 13, 14, 17, 18a, 23, 24, 26, 28, 29, 31, 39, 40, 41, 45, 46, 47, 48, 49, 51, 52. Kőrösi 2008. 31-32.) no correlation could be revealed between size and ageing. This statement has been verified by statistical tests (**Table 3.**). Dimensions of more importance highlighted only:

Among the lengths and widths of the skull, the median-saggital length [A-N (8)] of the frontal bone and the least breadth between the bases of the horn cores (31) are not age-dependant, no tendencies were observed in their growth. The median-saggital length of the frontal bone is measured between the acrocranion (A) and the nasion (N). According to the position of the Nasion (N) it may be in oral, medium or aboral position. The Nasion (N) was 62% in medium position, 28.5% in aboral position and 9.5% in oral position of the skulls examined. The examinations have also been carried out separately on medium and aborall positioned craniums. In both cases the regression function revealed the independence of size from age (**Table 3.**). Due to the low number of skulls with orally positioned Nasion (N), no separate scrutinization has been performed. The position of the Nasion (N) also affects the length of the viscerocranium [P-N (7)]. First I conducted the studies with all skulls, followed by the separate examinations of skulls with medium and aboral positioned Nasion (N). In all cases the studies revealed the independence of size from age (**Table 3.**).

The same can be stated on the longest [B-A (40)] and shortest [O-A (41)] height of the occipital region, which do not change with age as well. However, in the case of some dimensions the picture is not so clear. The frontal (total) length [A-P (1)] of the calvaria appears to grow until approx. 8-10 years according to the diagrams. Then it reaches its maximal length and stops changing (**Fig. 10.**). Th statistical tests did not reveal connection between age and size in all (1-16 years) individuals. I conducted the study without individuals older than 10 years, i.e. with the date in the age group of 1-10 years. According to the examination size remains to be independent from age. It is worth-trying to perform the study on a larger number of skulls under the age of 10, succeeded by the comparison of the results obtained. L. Bartosiewicz's research carried out on Red Pied Hungarian cattles revealed that there is no correlation between the growth of the frontal skull length and ageing (Bartosiewicz 1980. 23.)

The medial length of the palatine bone [Po-St (18a)] and the dental length of the palate [Po-Pd (17)] is independent from age.

Among dimensions independent from age I would highlight the dimensions of the horn, because it was presumed that there was a correlation between dimensions and age, but this assumption has been confuted. There is no increase in the width (45) and thickness ("height" 46) of horn core base radix according to the diagrams (**Figs. 11-12.**), despite the fact that the oldest cows had the largest horn bases. This may be caused by the genetic determination of the horn core size, as well as the low number of subjects. A subject with higher numbers may modify this presumption. In my opinion, hereditary attributions play a major role not only in the shape of the horn, but also in the length of the horn core and horn. Statistical tests revealed no correlation in all but one dimension (horn length (47a) with age, i.e. horn and horn core dimensions are independent from age. According to the statistical function, only horn length shows parallel growth (47a) with age (**Table 3.**).

The basal length [St-B (14)] of the neurocranium has an interesting picture. According to the diagrams the basal length does not change with ageing, what is also demonstrated by statistical analysis (**Table 3.**). However, the data of dimensions form two distinct groups (**Fig. 13.**), which may represent two different types of skull. The smaller skull type has a shorter basal length ranging from 158.7 to 175.8 mm, the larger type has longer basal length, ranging between 228.7 and 260.7 mm. The difference between the two size range is higher than 50 mm. Skulls with longer basal neurocraniums are more common.

At the horizontal [Ent-Ect (23)] and vertical (24) inner length of the orbita the decrease of sizes would be expected due to the age-related ossification. This change can be observed on bulls, but not on cows and oxen. This decrease occurring on bulls is caused by the extremely powerful ossification on he frontal bone and around the orbita (Photo 1). In my opinion, this thickening accompanied by bone deposition, and thus decrease of the size increases only to a certain age (about 10 years). The thickening stops after reaching a certain level of bone depositions. Because of the low number of bull skulls, this may be accepted only with doubts, and should be checked on a material containing more subjects. In my view, however, it is likely that based on the observed unified and powerful ossification of bull skulls, we would get the same result - a reduction of the internal dimensions of the orbit until a certain age, then stagnation - in case of more subjects. The horizontal [Ent-Ect (23)] and vertical (24) changes of the inner length of the orbita cannot be revealed on cows and oxen. This may mean the independence of dimensions from age, but may be the reason for this that in the case of cows and oxen the thickening or significant bone deposition in the orbital area cannot be observed (Photos 2-3), and the orbita of the Hungarian gray cattle may be of different shapes (oval, rectangular, round and oval), which may affect the examination results.

According to the diagrams the length of the nasal bone [N-Rh (12)] does not change with ageing, what is also demonstrated by statistical analysis (**Table 3.**). According to the length of nasal bone there are three types: skulls with long, medium and short nasal bone. Long-and medium-size ranges are distinguished in the diagram displaying no growth. Due to the small number of skulls with long nasal bone (2 pieces), those changes can not be observed. The linear regression analysis of skulls with medium (12 pieces) and short (7 pieces) nasal bones showed independence of changes in size and age (**Table 3.**).

4.3 Correlation between the changes of measurements and age cannot be observed:

Some of the studies carried out on a given skull size do not provide real results, as different types of skull sizes can be distinguished. Consequently, there is little data available for statistical analysis, thus in the case of 7 sizes (36, 42, 42a, 43, 43a, 49, 53. Kőrösi 2008.31-32.) examinations were not carried out.

Such sizes among the dimensions pertaining horn and horn basis are the distance between horns and horncora apexes (42, 42a), scale of expansion (43, 43a), because the value of these sizes depends on the shape of the horn and its stance (horn formation). Individual genetic endowments play a major role in shaping the Different horn transformations. Such testing could only be performed if individuals with the same horn formations were included in the study in higher numbers. Due to the small number of different horns and skull position, it makes no sense to carry out studies regarding the shape of the horn and the sizes of expansion (42, 42a, 43, 43a) in connection with ageing.

In case of other dimensions the test can be performed only if groups are created in advance within the given size complying to the type, and tests are performed within these groups, e.g. greatest breadth of the nasal bones [Fo-Fo (36)]. These dimensions can only be tested if adequate numbers of animals are available within a given type. Due to the small number of samples within the collection these dimensions were not examined.

The growth of the dorsal skull length of [N-P (7)] and the longest median-sagittal length of the frontal bone [A-N (8)] is not worth investigating, because both lengths are measured from the Nasion (N) measuring point. According to its location, Nasion (N) may be situated in different positions: top, middle and bottom positions. This significantly affects the length of the skull and the face.

The same can be said for the greatest breadth of the nasal bones [Fo-Fo (36)]. According to their width, nasal bones can be narrow and wide. The age-related changes would be worth investigating only if they were divided into two groups. The accurate distinction between the two groups would be possible by performing further analysis, therefore this examination was not carried out in this study.

Shape diversity of the lacrimal bone can be observed on the skull of the Hungarian Grey cattle. The lacrimal bone may be triangular or L-shaped, within the latter category it can have divergent, convergent and parallel versions of the lower stems. As a result, the dorsal length of the lacrimal bone [Fo-Lmo (49)] is not worth investigating in relation to age.

## *Summary*

The connection between skull dimensions of the Hungarian Gray cattle and age brought new results in several ways. Generally speaking, increased size can be observed in 21 cases, while decreased dimension can be scrutinized in 3 examples. 24 skull dimensions were independent of age, while in the case of 7 sizes a greater number of data is needed to perform the examination.

In general, the widths and lengths of the skull, the frontal bone and the facial cranium vary with age. Among length values the basal size of the cerebral cranium grows to a lesser extent, while the width dimensions change more significantly as age progresses. The area of the occipital region does not grow with age.

The correlation factor shows a close link between the change of size and the progress of age (**Table 3.**). In case of skullssize where correlation is apparent between size and age, I made three groups. Medium correlation is apparent between 40 and 60%, closer than medium correlation is apparent between 61 and 80% and there is a close correlation in case of values between 81 and 100%.

In case of 14 sizes (2, 3, 6, 10, 17a, 19, 21, 27, 30, 32, 33, 37, 44, 47a, Kőrösi 2008.31-32.) the correlation is medium, in case of 8 sizes (16, 20, 22, 25, 34, 35, 39, 50, Kőrösi 2008.31-32.) the correlation is closer than medium and in case of 2 sizes (18, 38, Kőrösi 2008. 31-32.) the correlation is very close.

The most unexpected changes occurred in several dimensions of denture and horn core bases. The length of the whole cheektooth row [P1-3+M1-3 (20)], premolar row[P1-3 (22)] and molar row [M1-3 (21)] is reduced due to intradental grinding as age progresses (Grigson 1974). As a result of the horizontal abrasion of the occlusal surface of the palm that is narrowing towards the root of the tooth the neighboring teeth are drawing closer to each other. That is the reason for shortening.

In the case of horn core dimensions one would expect that its size growth is correlated with age. However, studies have shown that in the case of cows and oxen only the horn length and the circumference of horn core radix increases with age. In case of the examined sizes the linear regression functions give the approximate annual growth of the size. Based on this the greatest growth is observed at the longest size of the horn and horn core.The length of the horn (47a) grows 10 mm, the circuit of the horn core base (44) grows 4,22 mm annually. Bartosiewicz observed in his studies annual growth of 18 mm in cows, and that of 38 mm in oxen (Bartosiewicz 2005. 310.).

The other dimensions pertaining horns and horn core are not changed. In my opinion, hereditary attributions play a major role not only in the shape of the horn, but also in the length of the horn core and horn. It has also a significant impact on horn dimensions, that what age was the calf castrated (Bartosiewicz 2005. 304.). This seems to be confirmed by the fact that in the Hungarian Grey Cattle collection in the Museum of Hungarian Agriculture one can see two ox skulls with extremely thick and long horns aged only 4-5 years (Kőrösi 2008. 204. 4th -5th oxen). These horn cores and horns are considerably longer than those of old skulls.

The expansion of studies regarding horn and horn core is necessary, because apart from the size of the horn base, the horn core diameter should also be scrutinized. Also, the testing should be carried out on a greater number of skulls, which may be used to verify or confute the changes observed in this article.

## References

BARTOSIEWICZ L. (1980): Change in skull proportions of cattle during ontogeny. *OSSA* **7** 19–31.

BARTOSIEWICZ, L. (2005): Skull formation in long horned cattle the Hungarian Grey. In: TECCHIATI, U., SALA, B. (eds.) *Archaeo-zoological studies in honour of Alfredo Riedel*, 303–312.

BÖKÖNYI, S., KÁLLAI, L., MATOLCSI, J., TARJÁN, R. (1964): Összehasonlító vizsgálatok az östulok és a szarvasmarha elülső lábközépcsontján, *Magyar Mezőgazdasági Múzeum Közleményei* **2** 3–24.

DRIESCH, von den A. (1976): A guide to the measurement of animal bones from archaeological sites. *Peabody Museum Bulletin* **1** Cambridge. 1–137.

DUERST, J. U. (1930): Vergleichende Untersuchungsmethoden am Skelett bei Säugern. In Abderhalden, Emil (Hrsg.): *Handbuch der biologischen Arbeitsmethoden*. Berlin–Wien, 125–530.

GRIGSON, C. (1974): The craniology and relationships of four species of Bos. 1. Basic craniology: *Bos taurus* and its absolute size. *Journal of Archaeological Science* **1** 353–379.

KŐRÖSI, A. (2008): A magyar szürke marha kraniometriai jellemzése. Magyar Mezőgazdasági Múzeum Budapest, *Mezőgazdaságtörténeti tanulmányok* **11** 1–303.

MATOLCSI, J. (1967a): A szarvasmarha végtagcsontjainak méretarányai, *Állattani Közlemények* 14 / 1-4, 81–88.

MATOLCSI, J. (1967b): Historische Erforschung der Körpergröße des Rindes auf Grund von ungarischem Knochenmaterial *Zeitschrift für Tierzüchtung und Züchtungsbiologie* **87 / 2** 89–137.

MATOLCSI, J. (1967c): A szarvasmarha testnagyságának változása a történelmi korszakokban Magyarország területén. *Agrártörténeti Szemle* **1-2** 1–38.

MATOLCSI, J. (1969): Összefüggések a szarvasmarha élősúlya és lábközépcsontjainak súlya között, *Állattani Közlemények* **16 / 1-4,** 99–106.