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Research paper

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DIACHRONIC CHANGES IN LONG-BONE DIMENSIONS AND RECONSTRUCTED STATURE FROM THE EARLY IRON AGE TO THE EARLY MEDIEVAL PERIOD: EVIDENCE FROM THE ZAYUKOVO-3 CEMETERY (KABARDINO-BALKARIA)

Abstract. This study investigates changes in skeletal long-bone dimensions in North Caucasus populations over a span of approximately 1,500 years (from 8th century BC to 7th century AD), using materials from the Zayukovo-3 polycultural cemetery (Kabardino-Balkaria Republic, Russia) as a case study. The research aims to reconstruct stature and assess morphological variability among individuals from three key cultural-chronological phases of the site: the Western Koban culture of the pre-Scythian period (8th–5th centuries BC), the Podkumok-Khumara cultural group of the Late Sarmatian period (1st–3rd centuries AD), and the Early Alanian period (5th–7th centuries AD). Methods employed include paleoanthropological analysis, reconstruction of fragmented skeletal remains, osteometric measurement, stature estimation, and statistical processing of the resulting data. The analysis revealed statistically significant differences and similarities among the compared groups. Males from the Koban and Alanian stages displayed morphological similarity, while female stature showed no significant difference between the Koban and Sarmatian samples. The Koban population exhibited pronounced sexual dimorphism in skeletal proportions. Sarmatian males had the lowest mean stature (163 cm) and were morphologically distinct from the other groups. Reconstructed stature was 169 cm for Koban males and 168 cm for Alanian males. These results align with recent paleogenetic studies suggesting biological continuity between Koban and Alanian populations. The findings underscore the value of osteometric analysis in paleoanthropological research and highlight the complex biological dynamics of ancient North Caucasus populations. They indicate both long-term continuity across certain archaeological cultures and the potential impact of external components during the Sarmatian period. These patterns warrant further verification through interdisciplinary studies.

Keywords: West Koban archeological culture; Late Sarmatian period (Podkumok-Khumara-type monuments); Alans; North Caucasus; Early Iron Age; Middle Ages; stature reconstruction; morphological variability; biological anthropology

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Исследовательская статья

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ДИНАМИКА ПРОДОЛЬНЫХ РАЗМЕРОВ СКЕЛЕТА ЧЕЛОВЕКА ОТ РАННЕГО ЖЕЛЕЗНОГО ВЕКА ДО РАННЕГО СРЕДНЕВЕКОВЬЯ НА ПРИМЕРЕ МАТЕРИАЛОВ МОГИЛЬНИКА ЗАЮКОВО-3 (КАБАРДИНО-БАЛКАРИЯ)

Аннотация. Работа посвящена исследованию динамики продольных размеров скелета у населения Северного Кавказа на протяжении полутора тысяч лет (с VIII в. до н.э. по VII в. н.э.) на примере материалов поликультурного могильника Заюково-3 (республика Кабардино-Балкария). Работа направлена на реконструкцию длины тела и анализ морфологической изменчивости представителей трёх ключевых культурно-хронологических этапов функционирования могильника: западной кобанской культуры (VIII–V вв. до н.э.) предскифского времени, культурной группы памятников типа Подкумок-Хумара позднесарматского времени (I–III вв. н.э.) и раннего аланского времени (V–VII вв. н.э.). Методы исследования включали палеоантропологический анализ, реставрацию фрагментированных костных останков, остеометрию, реконструкцию длины тела, а также статистическую обработку полученных данных. Основные результаты выявили статистически значимые различия и сходства между группами. Установлено морфологическое сходство между мужчинами кобанского и аланского этапов, а также отсутствие достоверных различий в длине тела у женщин кобанской и сарматской групп. При этом для кобанской общности характерен выраженный половой диморфизм в пропорциях скелета. Мужчины сарматского этапа оказались наиболее низкорослыми (163 см) и морфологически обособленными. Реконструированная длина тела у кобанских мужчин составила 169 см, у аланских – 168 см. Полученные данные находят отклик в современных палеогенетических исследованиях, указывая на возможную биологическую преемственность между кобанским и аланским населением. Выводы работы подтверждают важность остеометрического анализа как одного из ключевых инструментов современных палеоантропологических исследований. Результаты свидетельствуют о сложной динамике биологического субстрата древнего населения Северного Кавказа, где прослеживается как преемственность представителей различных археологических культур, так и возможное влияние инокультурных компонент (сарматское время). Обнаруженные закономерности требуют дальнейшего подтверждения в рамках междисциплинарных исследований.

Ключевые слова: Западная кобанская культура; позднесарматское время (памятники типа Подкумок-Хумара); аланы; Северный Кавказ; РЖВ; Средневековье; длина тела; морфологическая изменчивость; биологическая антропология

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Introduction

Human occupation of the North Caucasus spans several millennia. The Greater Caucasus Range has functioned both as a natural barrier and as a contact zone between sedentary and nomadic groups. Transitions from nomadic to semi-nomadic or fully sedentary ways of life repeatedly promoted population admixture across historical periods, contributing to the complex gene pool of the region's inhabitants. Processes of population replacement or mutual assimilation remain poorly understood and demand integrated investigation by bioarchaeologists, paleoanthropologists, and geneticists.

Due to the complex dynamics of population change in the North Caucasus, archaeological sites in the North Caucasus frequently comprise long-occupied settlements and stratified burial complexes. The sequential superposition of archaeological cultures within the same territory is especially characteristic of the Ciscaucasian steppes and the North Caucasian foothills. Despite extensive archeological research and numerous hypotheses proposed by leading Caucasian scholars, many questions persist, particularly, concerning the origins and cultural affiliations of the region's indigenous populations.

Most experts currently recognize the Koban cultural-historical community (hereafter CHC) as one of the indigenous populations of the North Caucasus [1]. The formative phase of this culture is dated to the mid-12th – mid-9th centuries BC, while its decline is linked to Scythian-Sarmatian influence during the second half of the 7th and early 4th centuries BC [2]. At the Zayukovo-3 cemetery, most Koban-culture burials belong to the 7th–5th centuries BC, corresponding to its final stage.

The CHC probably emerged from local variants of the North Caucasian substrate [3] of the Late Bronze Age [4] in the Kislovodsk area. Settlements dated to the 16th–10th centuries BC have been identified there; these are chronologically connected to later regional sites that yielded ceramics comparable to those of the early Koban culture [1].

The nature of interactions between the Koban CHC and Scythian-Sarmatian cultures remains debated. Some researchers regard close contacts as indisputable [5], whereas others argue that Koban monuments in the mountainous foothills show no direct connection with nomadic cultures [4].

The Scythian period in the North Caucasus ended with the arrival of Sarmatian nomadic tribes in the 3rd century BC [6]. Sarmatian expansion occurred in two main waves: the conquest of the Kuban lowland territories (4th century BC – 1st century AD) and the broader Sarmatization of the North Caucasus (3rd–1st centuries BC) [7]. In Sarmatian sites of the 2nd–1st centuries BC, burial structures reminiscent of Koban traditions (8th–4th centuries BC) [8] and similarities in ceramics are observable. At the same time, evidence exists of military conflicts between Kobans and Sarmatians [9].

Among Sarmatian-period communities in the North Caucasus, the Podkumok-Khumara cultural group is distinctive. It was distributed primarily in mountainous areas from the 1st century BC to the 4th century AD. The origin of this group is linked to migrations from the plains and foothills of the central and eastern North Caucasus [10]. Recent studies have noted morphological similarity between its bearers and Late Sarmatian populations [11]. Sarmatian dominance declined with the expansion of Alanian tribes at the end of the 4th century AD, leading to cultural assimilation and the formation of the Alanian culture in the central North Caucasus (5th–first half of the 8th century AD). Paleoanthropological data for populations associated with Podkumok-Khumara-type sites remain scarce, despite the fact that the period from the 3rd century BC to the 3rd century AD corresponds to the main phase of Sarmatian penetration into Ciscaucasia and the broader Caucasus region.

The Alanian tribes succeeded the Sarmatian period, although the process of Alanian ethnogenesis remains debated. Some researchers propose that certain Sarmatian tribes contributed to it [12]. Recent studies, including paleogenetic evidence, however, indicate that the Alanian CHC formed during the Middle to Late Sarmatian period on an autochthonous North Caucasian substrate, incorporating a Late Sarmatian genetic component through nomadic migrations [13, 14].

Population interactions merit particular attention during the most sensitive phases of cultural development – namely, at the stages of emergence and decline. Paleoanthropological methods enable the detection of morphological changes among representatives of various cultures.

Materials and methods

The skeletal material examined in this study derives from individuals interred at the Zayukovo-3 cemetery (Zayukovo village, Kabardino-Balkaria). Excavations are being conducted jointly by the State Historical Museum, Kabardino-Balkarian State University, and the Institute of Archaeology of the Russian Academy of Sciences, under the direction of archaeologists A.S. Kadieva and S.V. Demidenko. The cemetery was in use from the 8th century BC to the 7th century AD [15]. The site is characterized by complex stratigraphy, multiple occupational phases, and polycultural composition.

The present analysis focuses on the three cultural-historical communities most abundantly represented at the cemetery:

– Western Koban archaeological culture (8th–5th centuries BC);

– Podkumok-Khumara-type cultural group of monuments (hereafter Podkumok-Khumara-type CGM) of the Late Sarmatian period (1st–3rd centuries AD);

– Alanian archaeological culture (5th–7th centuries AD).

The paleoanthropological material is fragmented: earlier burials were frequently disturbed by subsequent interments and by ancient looting. To date, the complete skeletal assemblage recovered during excavations conducted between 2014 and 2022 has been restored and analyzed using a range of methods. The collection is currently housed in the Research Institute and Museum of Anthropology, Moscow State University.

Sex and age-at-death determinations were performed following standard anthropological protocols [16–19] (Table 1).

Table 1. Sex and age-at-death characteristics of the material

	Male	Female	Indeterminate
Western Koban	16	18	15
Podkumok-Khumara	17	23	7
Alans	19	13	5
Total	136		

This study utilized only the maximum lengths of the major limb bones: humerus (H1), ulna (U1), radius (R1), femur (F1), tibia (T1), and fibula (Fi1) [17, 20]. Cluster analysis and multidimensional scaling were performed using mean values of these lengths.

Stature was reconstructed for individuals from each chronological phase using established regression formulae. The most appropriate equation for each population was selected based on known stature distributions [21–23]. Depending on skeletal preservation, stature was estimated from one or more available long-bone lengths.

Differences in mean reconstructed stature between chronological groups were evaluated using Student's t-test. All statistical analyses were conducted with the STATISTICA software package (Excel module).

Results

Cluster analysis and multidimensional scaling revealed that males from the Koban and Alanian periods are morphologically most similar to each other. A comparable degree of similarity is evident between males and females of the Podkumok-Khumara-type CGM (Late Sarmatian period). Thus, similar morphological patterns are observed both within a single population (allowing for sexual dimorphism) and between two male groups

separated by more than 1,000 years and belonging to different occupational phases of the Zayukovo-3 cemetery. This pattern suggests morphological continuity in the male lineage across these periods. Confirmation of this hypothesis will require larger and more representative samples.

Sarmatian males are morphologically distant from both Koban and Alanian males (Fig. 1A). A marked separation is also evident between Koban males and females (Fig. 1B), which may reflect pronounced sexual dimorphism, different genesis of males and females within the Koban population, or the limited observations. In contrast, Sarmatian males and females cluster together, alongside Koban females. Alanian females form a relatively distinct group, a pattern clearly visible in the scatter plot.

Comparison of reconstructed statures among the three samples revealed significant differences between Koban and Sarmatian males ($p < 0.05$) and between Sarmatian and Alanian males ($p < 0.05$), but not between Koban and Alanian males (Fig. 2). Among females, no significant stature differences were observed between the Koban and Sarmatian samples (Fig. 2), whereas Alanian females differed significantly from both ($p < 0.05$).

Discussion

The earliest attempts to characterize the physical appearance of Koban CHC representatives using craniometric data were undertaken by V.P. Alekseev [24]. Subsequent work by M.M. Gerasimova and D.V. Pezhemsky [25] demonstrated that the Koban craniological type is predominantly dolichocranic, narrow-faced, with a prominently projecting nose and marked Europid morphology. Notably, similar cranial characteristics (sharply dolichocranic, narrow-faced Europid type with a narrow nose and high cranial vault) are observed in Early Alanian populations [26]. To date, evidence of continuity between Koban and Alanian populations is apparent at both morphological and genetic levels [27].

Osteometric data for the Koban CHC are considerably scarcer than craniometric data. Previous studies (Klin-Yar III) reported a mean male stature of 167.1 cm and a female stature of 154.3 cm (derived from a single individual) [28]. The present results from Zayukovo-3 (169 cm for males, 162 cm for females) diverge from these earlier estimates. Accordingly, Koban males at Zayukovo-3 fall within the tall stature category, whereas females are of medium stature. Multivariate analyses further indicate that Koban males and females differ markedly from one another in long-bone proportions. This pattern may reflect distinct genetic contributions to the male and female segments of the population and warrants further investigation.

The craniology of Sarmatian-period populations has been extensively studied. Most individuals associated with the Sarmatian archaeological culture exhibit a meso-brachycranial morphological type [29]. During the Middle Sarmatian period, however, a dolicho-mesocranial variant also appeared, which became predominant in the Late Sarmatian period [30].

Osteometric studies of Early Sarmatian populations that is associated with the cemeteries of the Lower Volga region are rare but report mean statures of 164.2 cm for males and 155.4 cm for females, describing them as medium-statured and robust [31]. These values closely match those obtained in the present study for the Late Sarmatian (Podkumok-Khumara-type CGM) series at Zayukovo-3 (163 cm for males, 155.6 cm for females). Likewise, the reduced sexual dimorphism noted in Early Sarmatian groups [31] is consistent with our findings. Our results also align closely with those reported by B.V. Fiershtein in the 1970s for Sarmatian series from the Lower Volga region, where she similarly characterized the population as medium-statured and stocky [32].

The population associated with the Podkumok-Khumara-type CGM corresponds to the Late Sarmatian phase (1st–3rd centuries AD) at the Zayukovo-3 cemetery. Paleoanthropological studies of this group remain scarce [33]. One rare example is a 4th-century AD burial from Levopodkumsky 1 (Kislovodsk Basin), where an individual attributed to this cultural group yielded a mesocranial skull of Europid morphology [33]. According to V.Yu. Malashev, the bearers of the Podkumok-Khumara-type CGM represent a Sarmatized autochthonous North Caucasian population that can be regarded as “pre-Alanian” [10]. At the same time, the proportions and

dimensions observed in the present study indicate a clear steppe component, as they closely resemble those documented for Sarmatian groups.

Sexual dimorphism in reconstructed stature is relatively weak in the Podkumok-Khumara-type CGM compared to the Koban group and is comparable to that observed in the Early Alanian sample. Multivariate analyses, however, reveal that Sarmatian females more closely resemble Sarmatian males in long-bone proportions than do females in the other two groups, suggesting greater genetic homogeneity. No analogous male–female similarity is evident in the other two groups. The Sarmatian group also exhibits the lowest mean stature among the others, which may be explained by several hypotheses, including the selective pressure of unfavorable environmental conditions.

Although the early centuries of the era coincided with the Roman Warm Period, a phase of relatively stable warmth and adequate humidity [34, 35], the 2nd–3rd centuries AD witnessed pronounced local climatic fluctuations toward cooling and aridization [36]. Given the comparable glacial dynamics of the North Caucasus and the Alps [34, 37], similar climatic instability likely affected the territory of Kabardino-Balkaria during the final centuries of the Early Iron Age. Analysis of bottom sediments from Lake Karakel (Western Caucasus) further reveals a sharp decline in bromine concentration from the second half of the 2nd to the 4th century AD, indicative of regional cooling [38]. Low temperatures are known to impair cartilage growth and reduce final limb length [39], which could explain the observed trends in morphological variability and the convergence of proportions between men and women during the Sarmatian period. Additionally, severe environmental stress (chronic malnutrition, excessive physical labour, or psycho-emotional strain) can accelerate skeletal maturation in females [40].

An alternative hypothesis for the reduced sexual dimorphism in the Sarmatian-period group invokes high levels of physical activity in both sexes [41]. Consistent with this interpretation, skeletal remains from the Sarmatian stage (both males and females) exhibit pronounced muscle attachment sites and frequent degenerative-dystrophic changes in the spine (particularly the lumbar region) and major joints (shoulder, hip, knee, and ankle). Many of these alterations are not age-related and appear disproportionate to expected wear patterns.

Osteometric results indicate that Early Alanian males were of medium stature. Their reconstructed stature values closely resemble those of Koban males and differ significantly from the Sarmatian-period population. Multivariate analysis failed to reveal close morphological similarity between Early Alanian males and females; in multidimensional space, Alanian females occupy a relatively distinct position (Fig. 1A). Nevertheless, the separation between Alanian males and females is considerably less pronounced than that observed between Koban males and females.

Despite extensive research on the Early Alanian archaeological culture and its bearers, osteometric data remain limited. A previous study of the Beslan cemetery (primarily 2nd–4th centuries AD) reported a mean male stature of 165 cm, with considerable individual variation (some males exceeding 190 cm), and approximately 155 cm for females [42]. The present study yielded higher values (168 cm for males, 162 cm for females). However, it is worth noting that the Beslan cemetery belongs primarily to the early stage of the Alanian culture (2nd–4th centuries AD), while the Alanian stage of functioning of the Zayukovo-3 cemetery corresponds mainly to the 5th–7th centuries AD. Consequently, the observed differences may be due to both chronological and territorial variability of the ancient Alanian population. It is noteworthy that ancient sources, including Ammianus Marcellinus in his *Res Gestae*, also described the Alans as notably tall [43].

Chronological trends in stature also merit brief consideration. Female stature exhibits a gradual increase from the Early Iron Age to the early medieval period. In contrast, male stature displays undulating patterns across periods, possibly reflecting episodic population replacement, particularly the influx of steppe-derived genetic components. At the same time, the well-documented influence of external factors on human growth and development [44] indicates that these epochal fluctuations in stature among ancient populations are likely linked to shifting social and environmental conditions.

Some of the trends identified from the current osteometric data may shift as sample sizes increase. Nevertheless, the observed pattern of biological continuity, evident not only between chronologically proximate

groups but also between cultural-historical communities separated by centuries, represents a major finding and a critical direction for future research at the Zayukovo-3 cemetery. This is particularly significant given the unresolved questions surrounding the origins of females from the Koban, Sarmatian, and Early Alanian phases, which will require further interdisciplinary investigation.

Conclusion

The present data reveal morphological similarities between individuals from the Western Koban and Early Alanian archaeological cultures at the Zayukovo-3 cemetery. This affinity may reflect not only shared genetic heritage but also comparable environmental conditions that favoured the development of similar adaptive morphological patterns.

In contrast, the Sarmatian (Podkumok-Khumara-type CGM) population is clearly distinct. Its characteristics point to a different genetic substrate compared with both the preceding and subsequent groups, most likely resulting from the incorporation of a nomadic steppe component. These interpretations remain provisional and require further testing through larger comparative samples, paleogenetic analyses, and additional paleoanthropological studies.

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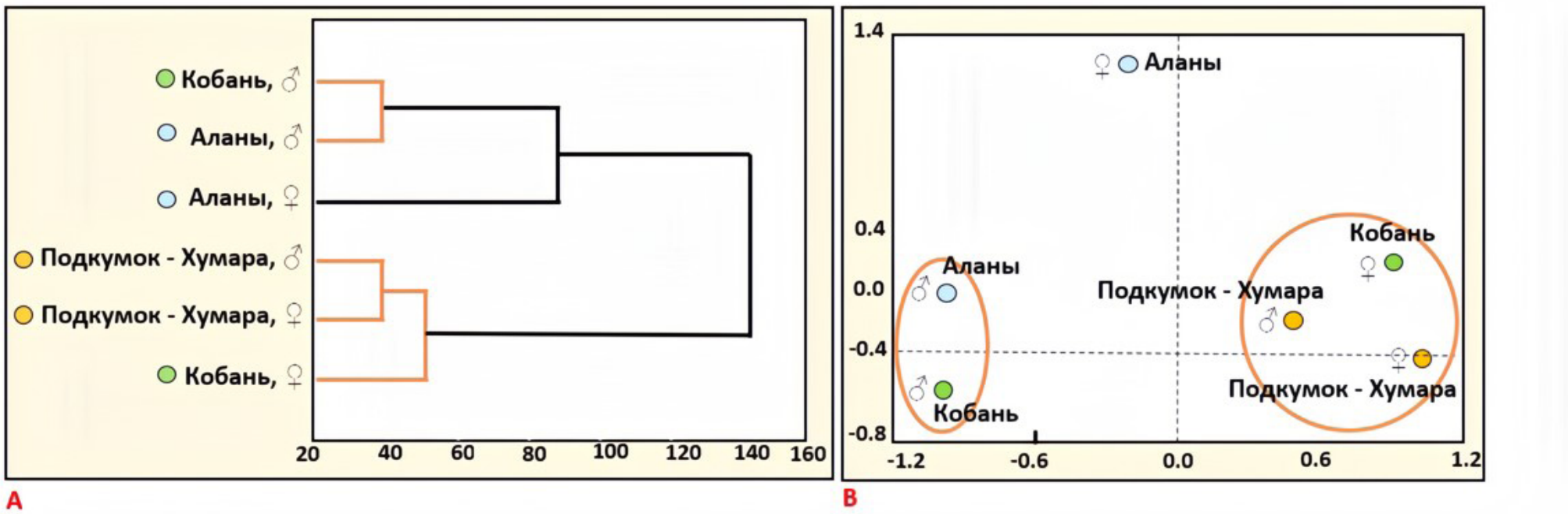
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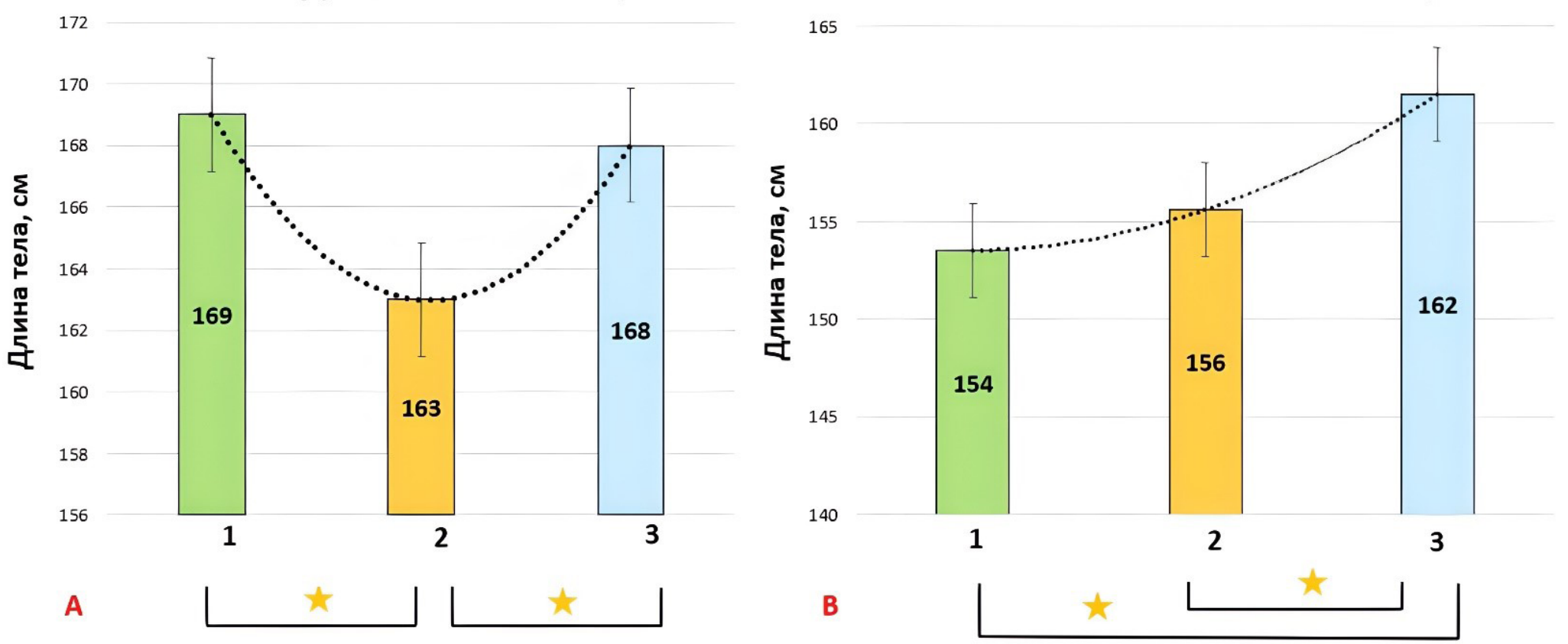
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