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Comparative anatomical characteristics of the distal parts of bear and human limbs

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ABSTRACT

BACKGROUND: The comparative morphology of the human and animal skeletons has been incompletely described in the forensic medical and anthropological literature. Moreover, bones of the distal parts of bear limbs are anatomically similar to those of humans. Together with some features of the bear's skeleton, poor preservation, absence of claws, and incomplete remains, difficulties and errors may occur during identification.

AIM: To create an illustrative material describing morphological features important for the identification of each element of the distal parts of bear limbs in comparison with humans.

MATERIALS AND METHODS: Preparations of the distal parts of the right thoracic and right pelvic extremities of the bear were made using osteological materials. The missing talon phalanges of a bear and bones of a human hand and foot were taken from the institute collections. The International Veterinary Anatomical Nomenclature was used to describe the anatomical features of bear bones, and the latest recommendations of International Anatomical Terminology were considered for human bones.

RESULTS: Each bone of the bear's hand and foot was described in comparison with a similar human bone. For greater versatility, descriptions were made in terms of the international zoological nomenclature. For all bones, except for distal sesamoid bones, high-quality photos are provided for aspects that are important for identification. Comparative anatomical analysis showed that the bones of the wrist differ to a greater extent, whereas all tarsal bones, which are part of the human foot, had analogs in the bear foot and had closer measurements. The articular surfaces of the heads of the metacarpals and metatarsals showed specific ridges articulating with the cutouts at the bases of the proximal phalanges of the fingers. In addition, the bear's hand and foot contained numerous inset sesamoid bones and claw-like processes on the distal phalanges of the fingers.

CONCLUSION: Comparative anatomical analysis showed similarities in the structures of the bones of the hand and foot of a brown bear and a human caused by foot walking. Owing to the morphological similarity, bone identification can be difficult. The set of features described in the article, which are specific to bear bones, in combination with illustrative material will help in identifying bones more accurately, even for individual bones.

Keywords: human and animal bones; comparative anatomy; brown bear; Ursidae.

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Сравнительно-анатомическая характеристика дистальных отделов конечностей медведя и человека

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АННОТАЦИЯ

Обоснование. Сравнительная морфология скелета человека и животных в судебно-медицинской и антропологической литературе описана неполно. При этом разрозненные кости дистальных отделов конечностей медведя анатомически схожи с человеческими в силу стопохождения, что в совокупности с некоторыми особенностями скелета медведя, плохой сохранностью, отсутствием когтей и некомплектностью останков может вызвать затруднения и ошибки в процессе идентификации.

Цель исследования — создание иллюстративного материала с описанием важных для идентификации морфологических особенностей каждого элемента дистальных отделов конечностей медведя в сравнении с аналогичными костями человека.

Материалы и методы. Подготовлены препараты дистальных отделов правой грудной и правой тазовой конечностей медведя в соответствии с методикой подготовки остеологических препаратов. Недостающие когтевые фаланги медведя и кости кисти и стопы человека взяты из коллекционных материалов. Для описания анатомических особенностей костей медведя использована Международная ветеринарная анатомическая номенклатура, для костей человека учитывались последние рекомендации Международной анатомической терминологии.

Результаты. Описана каждая кость кисти и стопы медведя в сравнении с аналогичной костью человека. Для всех костей, за исключением дистальных сесамовидных, приведены качественные фото в ракурсах, имеющих значение для идентификации. Сравнительно-анатомический анализ показал, что кости запястья отличаются в большей степени, тогда как все кости предплюсны, входящие в состав стопы человека, находят свои аналоги в стопе медведя и ближе по размерным характеристикам. Суставные поверхности головок костей пясти и плюсны имеют характерные гребни, сочленяющиеся с вырезками в основаниях проксимальных фаланг пальцев. Кроме этого, для кисти и стопы медведя характерно наличие большого количества вставочных сесамовидных косточек, а также когтевидного отростка на дистальных фалангах пальцев.

Заключение. Сравнительно-анатомический анализ показал сходства в строении костей кисти и стопы бурого медведя и человека, обусловленные стопохождением. Из-за морфологической близости идентификация костей бывает затруднена. Описанный в статье набор признаков, характерных для костей медведя, в сочетании с иллюстративным материалом поможет в определении даже разрозненных костей дистальных отделов конечностей.

Ключевые слова: кости человека и животных; сравнительная анатомия; бурый медведь; Ursidae.

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熊和人类远端肢体的比较解剖学特征

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摘要

论证。法医和人类学文献对人类和动物骨骼的比较形态描述不完整。与此同时，熊四肢远端零散的骨骼在解剖学上与人类骨骼相似，这是因为它们有脚印。再加上熊骨骼的一些特殊性、保存不善、没有爪子和遗骸不完整，可能会在鉴定过程中造成困难和错误。

研究目的是创建说明性材料，描述与类似的人类骨骼相比，熊四肢远端部分每个元素的形态特征对于识别很重要。

材料和方法。熊右侧胸肢和右侧骨盆肢远端部分的制备是按照骨学制备方法进行的。熊缺失的爪趾骨和人的手脚骨取自收藏材料。《国际兽医解剖命名法》用于描述熊骨骼的解剖特征。至于人类骨骼，则参考了《国际解剖术语》的最新建议。

结果。熊的每块手骨和脚骨都与人类的类似骨骼进行了对比描述。为了更具有普遍性，描述采用了《国际动物学命名法》。对于所有骨骼，除了远端芝麻状骨骼，都提供了与识别相关的角度的高质量照片。比较解剖学分析表明，腕骨的差异较大，而作为人类足部一部分的所有跖骨都能在熊足中找到类似物，而且在大小特征上更为接近。掌骨和跖骨头的关节面具有特征性的脊，与手指近端指骨基部的切口相连。此外，熊手和熊脚的特征还包括手指远端指骨上有大量的芝麻状骨突和爪状突起。

结论。比较解剖学分析表明，棕熊和人类的手和脚的骨骼结构因脚部行走而具有相似性。由于形态上的相似性，骨骼的识别可能比较困难。文章中描述的熊骨骼的一系列特征，结合说明性材料，将有助于更准确地确定其隶属关系，即使是根据肢体远端部分的单个骨骼。

关键词：人类和动物骨骼；比较解剖学；棕熊；Ursidae。

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BACKGROUND

Identifying the species affiliation of skeletonized remains of distal limbs of a large mammal to exclude their human origin is a rare task [1, 2]. In most cases, the association of bones to one or another animal species can be determined by comparative anatomy facilitated by the presence of obvious morphological features. However, the comparative morphology of human and animal skeletons in forensic and anthropological literature is lacking [4].

The brown bear (Ursus arctos) is the sole representative of the Ursidae family found in Central Russia and the largest terrestrial predator in Europe. Approximately two-thirds of the world population of brown bears is distributed across the territory of our country [5]. The body length of the brown bear ranges from 170 to 280 cm and the height at the withers from 90 to 110 cm. At these sizes, the mass of an adult brown bear can range from 60 to 300 kg. In contrast, foreign literature has described cases of black bears, which are inferior in size to brown bears. Therefore, because the growth and weight parameters of the animal may coincide with those of humans, relying on the size characteristics of bones is not recommended.

The presence of claw phalanges is a clear diagnostic criterion, although bear limbs are typically found without claws, as they are hidden during carcass cutting [6, 7]. The scattered bones of the distal parts of bear limbs resemble human limbs, as their structure supports the entire foot (foot walking). This, along with features of the bear skeleton, poor preservation, absence of claws, and incomplete limbs, can cause identification difficulties and errors [8–11].

In the initial stages of work with bone material, comparative anatomy is the most accessible and fundamental approach and a crucial tool for specialists engaged in fieldwork and laboratory-based research [3, 9]. Several studies have focused on the identification of bones of the distal limbs of bears using the comparative anatomical method [1, 2, 9, 12]. However, these studies lack comparative anatomical characteristics (e.g., they often omit the description of the appendicular [pea-shaped] bone of the bear's hand) or qualitative illustrative material that facilitates the identification of individual bones. Additionally, the nomenclature employed varies. In some instances, anatomical nomenclature of human bones is used, and in others, arbitrary descriptions are applied. Moreover, the International Veterinary Nomenclature, which is universal for animal bones, is utilized [13].

This study aimed to create illustrative material that comprehensively describes the morphological features that are crucial for the identification of each element of the distal limbs of the bear, in comparison with human bones.

MATERIALS AND METHODS

The initial phase of the study involved preparing the distal limbs of the bear, as this material is scarce and model objects is not always available.

The preparations were conducted in five stages: boiling, dissection, maceration, bleaching and degreasing, and strengthening. Initially, the material was represented by refreshed, salted, and dried bear paws. The preparation commenced with boiling, with the addition of sodium bicarbonate. Once the meat come off easily and the ligaments remained intact, dissection was possible. The position of each element was fixed with an image and a special marker to prevent errors, thus allowing further work to determine whether the object belonged to one or another section of the hand or foot. Maceration in water was conducted for a week. For bleaching and degreasing, the bones were immersed in a 5% hydrogen peroxide solution [14]. For strengthening, the bones were impregnated with a BF-4 glue solution and 90% alcohol in a 1:1 ratio. As a result, preparations of scattered bones of the right front and right hind limbs of the bear were created.

When skinning a carcass, hunters leave the claws on the skin; hence, the phalanges of the fingers were missing from the specimen obtained. The phalanges of a bear from the archaeological collection of the Laboratory of Scientific Methods of the Institute of Archaeology of the Russian Academy of Sciences were used. Bones of the hand and foot of a young male from the collection of the Department of Anthropology, Faculty of Biology, Lomonosov Moscow State University, were utilized as reference material.

Images of the bones were taken with a Canon EOS 6D camera, Canon EF 24–105 mm f/4L IS USM lens, on a uniform background with a scale bar.

The International Veterinary Anatomical Nomenclature in translation and Russian terminology of Professor Nikolai V. Zelenevsky [13] were applied to describe bear bones. For human bones, the latest recommendations of the International Anatomical Terminology were used.

RESULTS

Study subjects (participants)

Osteological preparations of the distal parts of the right thoracic and right pelvic limbs of a brown bear without claw bones and of the right hand and right foot of a human were utilized. The distal phalanges of another individual brown bear were used for completeness.

Main results

The human and bear hand skeleton (distal part of the thoracic limb) includes the carpal bones, metacarpals, phalanges, and sesamoid bones.

Scapholunate bone. The first bone of the proximal wrist (thumb side) of the bear, the scapholunate (*os scapholunatum*) or radial-intermediate (*os carpi intermedioradiale*), is an analog of the human scaphoid and lunate bones (Fig. 1). The bear's scapholunate bone was formed by the fusion of carpal bones, namely, the radius and intermediate and sesamoid bones,

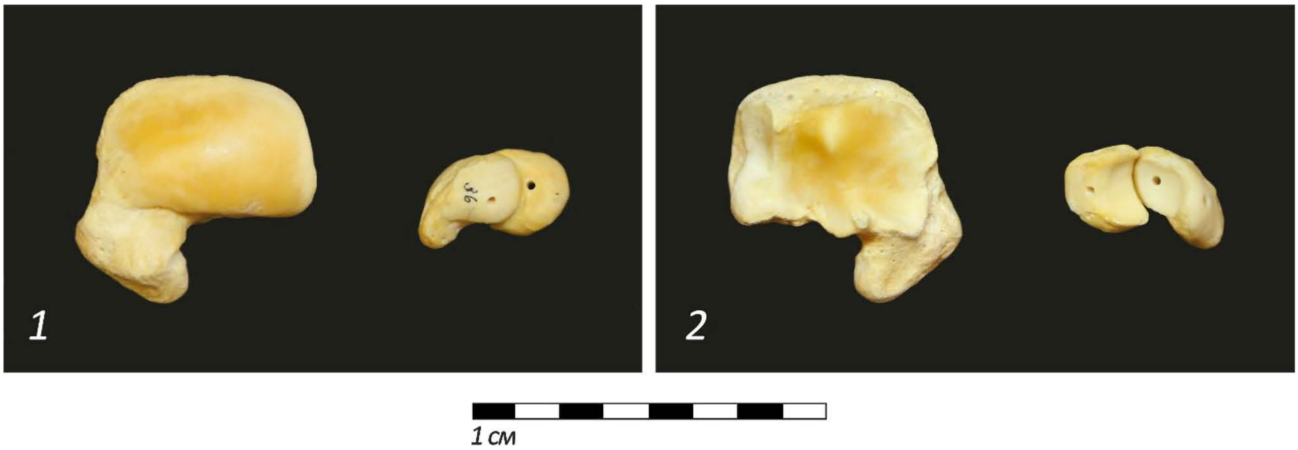

Fig. 1. Bear scapholunate and human scaphoid and lunate: *1* — proximal view; *2* — distal view.

which provided stable support and force to the wrist during movement [15]. The carpal radius of the bear corresponds to the human scaphoid, formed by fusion of the metacarpus and radius. Further, the intermediate bear bone corresponds to the human lunate [16].

The scapholunate bone is the largest bone of the wrist. It has a rectangular shape, and its proximal articular surface is convex and articulates with the radius of the forearm. On the distal surface, two vertical and two horizontal concave articular surfaces are visible for articulation with the first, second, third, fourth, and fifth (fused) bones of the distal row of the wrist. From the inferior medial corner of the bone, a palmar muscular spur is observed, which serves as the attachment point for the muscles of the first finger. On the lateral surface of the outgrowth, the sulcus of the tendon of the radial wrist flexor and deep finger flexor can be found.

The scapholunate bone of the bear is larger than the human scaphoid and lunate bones. Its distal articular surface is characterized by the presence of characteristic separating ridges.

The ulnar bone (*os carpi ulnare*) of the bear's wrist is analogous to the human triangular bone (Fig. 2). The bone is rhombus-shaped and flattened anteroposteriorly. The proximal part has upper and lower slightly concave articular surfaces, which are adjacent to the styloid process of the ulnar bone and to the carpal bone (analog of the pisiform bone), respectively. Medially, closer to the palmar surface (in the lower corner of the rhombus), a small articular surface for articulation with the scapholunate bone was noted. The distal end of the bone features a concave articular surface that enables articulation with the fourth bone of the distal carpal row, which is analogous to the hook bone. While the literature reports the presence of articulations with the third bone of the distal row of the wrist, this observation has not been confirmed in our material. The palmar surface of the rhombus is rough, with feeding holes and notches, and is equipped with a tubercle for muscle attachment.

In contrast to the triangular configuration of the wrist bone in humans, the ulnar bone of the bear wrist is characterized by a flat surface area that is more than twice as large. Additionally, the articular surface for the styloid process of the ulnar bone is concave rather than convex.

Carpal accessory bone (*os carpi accessorium*) is the second largest wrist bone of the bear. It is analogous to the human pisiform bone (Fig. 3). The body of the bone is tapered toward the ends, and the distal end of the bone is characterized by the presence of two semilunar concave articular surfaces. The smaller concave surface (from above) is used for articulation with the styloid process of the ulnar bone and the larger one (from below) for connection with the

Fig. 2. Bear carpal ulna bone and human triquetral: *1* — proximal view; *2* — distal view.

Fig. 3. Bear pisiform and human pisiform: *1* — dorsal view; *2* — palmar view.

ulnar bone of the wrist (Figs. 4 and 5). The proximal end of the bone is rounded with a tuberosity on the palmar surface. It lacks common features with the human pisiform bone.

The distal row of bones of the bear's wrist consists of four bones.

The first carpal bone (*os carpale I*) is analogous to the human trapezoid bone (Fig. 6). It shows a convex proximal surface for articulation with the scaphoid bone and a concave distal surface for contact with the first metacarpal bone. The medial side is rough, lacking articular surfaces. Laterally, an elongated narrow articular surface for articulation with the second carpal bone is noted. Parallel to this surface is a sulcus for ligament attachment.

The first wrist bone of the bear and human trapezoid bone exhibit similarities, with identical size and several morphological features. Majority of the distal surface of both bones is occupied by the articular surface, which connects them with the first metacarpal bone. In the bear, the shape of this articular surface is concave, whereas in humans, it is convex/concave (saddle-shaped). The tubercle of the trapezoid bone is located on the palmar surface in both bones; however, in the human trapezoid bone, it is more developed. In the bear, the tubercle of the trapezium bone is the most protruding corner of the bone to the palmar surface.

The second carpal bone (*os carpale II*) is analogous to the human trapezoid bone (Fig. 7). It is triangular and flattened anteriorly and posteriorly and has four articular surfaces. Two of these are large, occupying almost the entire proximal face (for articulation with the scapholunate bone) and entire distal face (for articulation with the second metacarpal bone).

Fig. 4. Articulation of bear ulna and pisiform carpal bones and articulation of human triquetral and pisiform bones: *1* — lateral view; *2* — medial view.

Fig. 5. The first row of bear carpals and the first row of human carpals in articulation: proximal view is above, distal view is below.

Fig. 6. Bear first carpal and human trapezium: *1* — view from I metacarpal; *2* — view from second carpal (human trapezoid); *3* — view from scapholunate (human scaphoid).

Fig. 7. Bear second carpal and human trapezoid: *1* — view from II metacarpal; *2* — view from third carpal and scapholunate (human capitate and scaphoid); *3* — view from first carpal and scapholunate (human trapezium and scaphoid).

Medially, a narrow articular surface extending along the entire facet (for the first carpal bone) and, laterally, above and below, two small facets interrupted by an extra-articular surface (for contact with the third carpal bone) are found. The largest extra-articular surface is the dorsal surface.

The configuration of the second carpal and trapezoid bones is distinct. The former has a triangular shape, and the latter resembles a boot with the sole upwards. The number of articular surfaces is similar, comprising two large and two smaller surfaces. The largest extra-articular surface on both is the dorsal surface, which is triangular in shape. The bear's second carpal bone is slightly larger than the human equivalent, which is the smallest bone in the distal row of the wrist. However, the size of the second carpal bone of bears is not significantly different from the first.

The third carpal bone (*os carpale III*) is analogous to the human carpal bone (Fig. 8). It is flattened from the sides. Proximally, it has a convex oval articular surface (head) for contact with the scapholunate bone. The distal concave surface articulates with the third metacarpal bone. Medially, two small facets for contact with the second carpal bone and, laterally, a lambdoidal articular surface for the fourth bone of the distal carpal row are observed.

The bones of the bear and man exhibit a common structure plan, although numerous differences are noted when examined in greater detail. First, the third carpal bone of the bear is twice as large. The shape of the boneheads differs: rounded in the cephalic bone and elongated and oval in the third carpal bone. In the cephalic bone, the largest extra-articular surface is dorsal, whereas in the bear, the dorsal and palmar extra-articular surfaces are virtually equivalent.

The fourth wrist bone (*os carpale IV*) is an analog of the human hook bone (Fig. 9). Notably, these are the fourth and fifth fused bones of the wrist [15]. It has the shape of a cone with its apex directed proximally. At the base of the cone, distally, there is a concave articular surface for contact with the fourth and fifth metacarpal bones. The medial surface is weakly convex and H-shaped, facilitating articulation with the scaphoid and third carpal bones. The lateral surface is rounded and convex, enabling contact with the ulna of the wrist. Comparatively to all carpal bones, the dorsal surface is rough, providing an optimal surface for ligament fixation.

Fig. 8. Bear third carpal and human hamate: *1* — view from III metacarpal; *2* — dorsal view; *3* — view from scapholunate (human scaphoid); *4* — view from second carpal (human trapezoid); *5* — view from fourthcarpal (human hamate).

Fig. 9. Bear fourth carpal and human hamate: *1* — dorsal view; *2* — view from IV and V metacarpals; *3* — view from the third carpal (human hamate); *4* — view from scapholunate and carpal ulna (human scaphoid and triquetral).

The bear's fourth carpal bone is approximately twice the size of the human hook bone and lacks the hook-like outgrowth observed on the palmar surface of the latter.

The metacarpal bones (*ossa metacarpalia*) are present in bears and humans, with five bones in each species (Fig. 10). Similar to all tubular bones, the metacarpals of the bear have bases (proximal epiphyses), which pass into bone bodies and end in heads (distal epiphyses).

The bones are connected proximally by lateral articular surfaces on their bases and distally by ligaments. The base of each metacarpal has an articular surface for articulation with the distal row of carpal bones. The bear's metacarpal bones have a ridge in the middle of the head block, which ends in a coronoid on the palmar surface. The distinctive ridge, as well as the size and shape of the articular surfaces, is the defining feature differentiating the metacarpal bones of a bear from those of a human. The heads connect with the proximal phalanges of the fingers and sesamoid bones [2].

The shortest and most gracile metacarpal bone of a bear is the first metacarpal bone, and the largest is the fifth metacarpal bone. In the present study, the longest metacarpal was the fifth metacarpal, although according to literature data, the fourth metacarpal may also have the greatest length [15].

The bones of the fingers (*ossa digitorum manus*) are tubular bones that distally continue the metacarpal bones. Similar to humans, bears have two phalanges in the first finger and three phalanges in each of the remaining fingers.

The proximal phalanges (*phalanx proximalis*) include a base, body, and head (Fig. 11).

The base of the phalanx is characterized by a centrally concave articular fossa, which enables the blockage of the crest of the metacarpal head. The proximal phalanges of the bear's feet exhibit a compression in a dorsopalmar direction. The head of the phalanx is indicated by a block with a central sulcus, surrounded by rough surfaces and ligament fossae. Dorsally, the block of the head of the first phalanx displays a less pronounced sulcus and "butted" articular surface. This region of the proximal phalanx shows a high similarity to that of the middle phalanges, as it serves to articulate with the claw bone.

The proximal phalanges of the bear's hand are more massive than those of a human. The sulcus of the head block is more noticeable, and the fossa at the base has a semilunar shape. The general shape of the phalanges is approximately rectangular due to the large heads, and the human phalanges are cone-shaped. Compared to those of humans, the phalanges of the different rays of the bear exhibit similar lengths.

The middle phalanges (*phalanx media*) are approximately 1.5 times smaller than the proximal phalanges and are part of fingers II–V (Fig. 11). The proximal surface of the phalanx base is divided by a ridge into medial and lateral articular fossae. Dorsally, the crest of the base transitions into an extensor spur, and behind the crest on the palmar surface lies a flexor. The heads of the middle phalanges carry the articular blocks, which are distinct to this phalangeal system. The sulcus of the block is weakly expressed, and the articular surface extends 5–7 mm over the dorsal surface.

The middle phalanges of the bear's hand are larger than those of the human hand. In a manner similar to the proximal row, the phalanges of the bear are larger and more rectangular in shape and differ slightly in length. The ridges of the bases are well-expressed. In contrast, the human middle phalanges are cone-shaped, clearly differ in length between the rays, and lack pronounced flexor roughness and extensor ridges.

The distal phalanges (*phalanx distalis*), or claw bones (os unquiculare) (Fig. 12), exhibit a distinctive diagnostic feature in the form of a claw, which is distinct from the nail tuberosity of the human distal phalanx.

The proximal sesamoid bones (*ossa sesamoidea proximalia*) are shaped like cashew nuts (Fig. 13) and are located on the palmar surface of the joints between the metacarpal bones and proximal phalanges, 10 in number. Each joint contains two ossicles, which are up to 20 mm long and 10 mm wide. They have one concave articular surface for the heads of the metacarpal bones. The edges of the ossicles that point toward each other are smoother. The right and left sesamoid bones produce a flexor surface, through which the tendons of the finger flexors pass.

The distal sesamoid bones (*ossa sesamoidea distale*) are individually located on the palmar surface within the joint capsule between the middle and distal phalanges of the hand [15]. However, they are not represented in our material. Studies wherein the distal phalanges are absent in the material did not indicate distal sesamoid bones [2, 9, 12]. The distal sesamoid bones may have remained in the skin during skinning.

The skeleton of the foot (*skeleton pedis*) of bears and humans is composed of the tarsal bones, metatarsals, phalanges of the toes, and sesamoid bones.

The tarsal bones can be divided into seven categories: the talus and calcaneus (proximal row), cuboid and three cuneiform bones (distal row), and scaphoid, which is located between the rows.

The *talus* is connected dorsally to the tibia, plantarly to the calcaneus, and distally to the scaphoid (central) bone. Its width exceeds its length. The large structures of the talus include the body, neck, and head (Fig. 14).

The talus block exhibits an articular surface on its dorsal aspect that facilitates articulation with the tibia bones. Additionally, a substantial articular surface is found on the lateral surface of the block, along with a diminutive, narrow facet on the medial surface. These facilitate contact between the talus block and lateral and medial ankles. On the lower surface of the body, a concave posterolateral and convex anteromedial articular surface are observed. This is the articular surface of the calcaneus, divided by the sulcus of the talus.

The neck of the talus extends into the head, which has a hemisphere shape and serves as the articular surface for contact with the scaphoid bone.

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Fig. 10. Bear metacarpals in comparison with human metacarpals. Scale ruler segment — 1 cm. From top to bottom: dorsal view, palmar view, medial view (lateral for human), lateral view (medial for human), proximal view (bases).

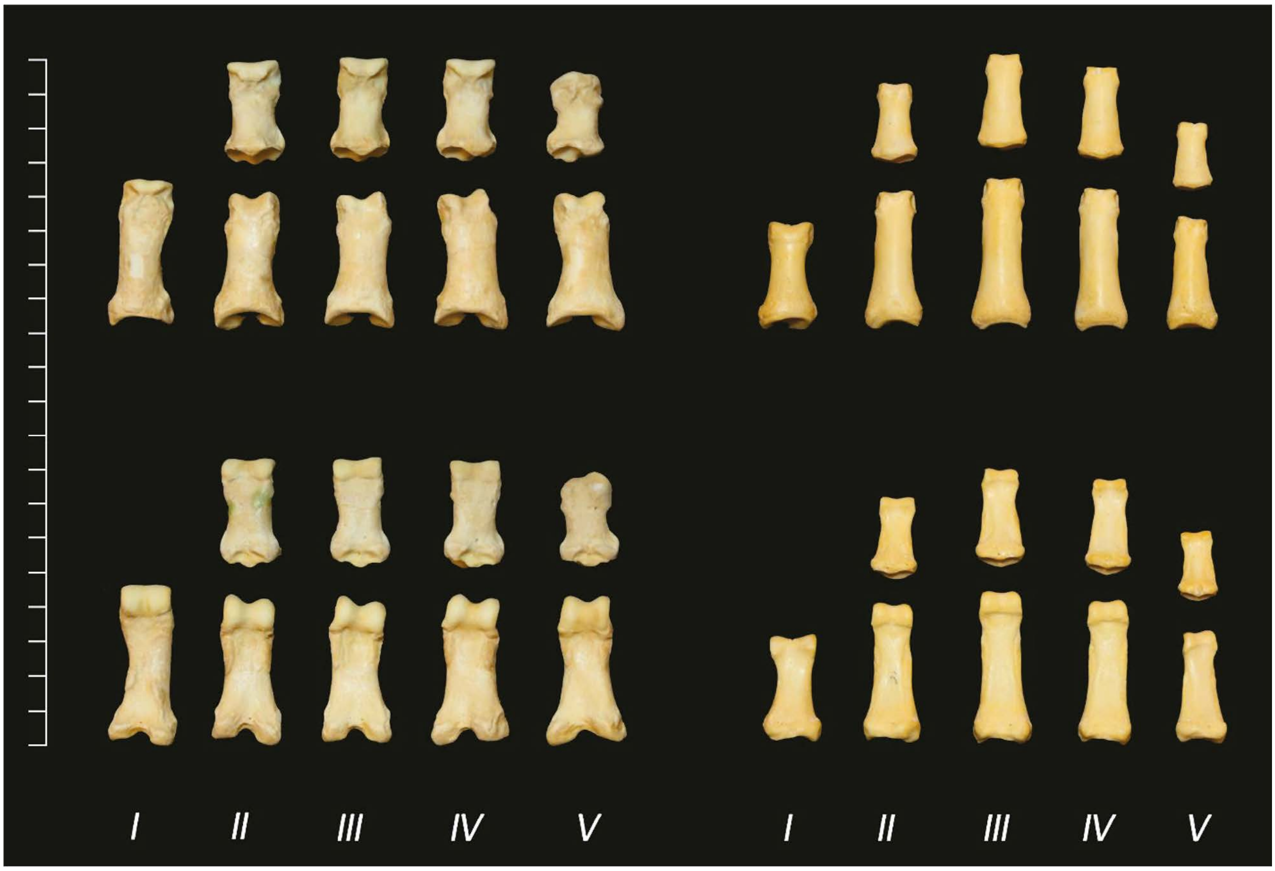

Fig. 11. Bear proximal and intermediate hand phalanges and human proximal and intermediate hand phalanges. Scale ruler segment — 1 cm. From top to bottom: dorsal view, palmar view.

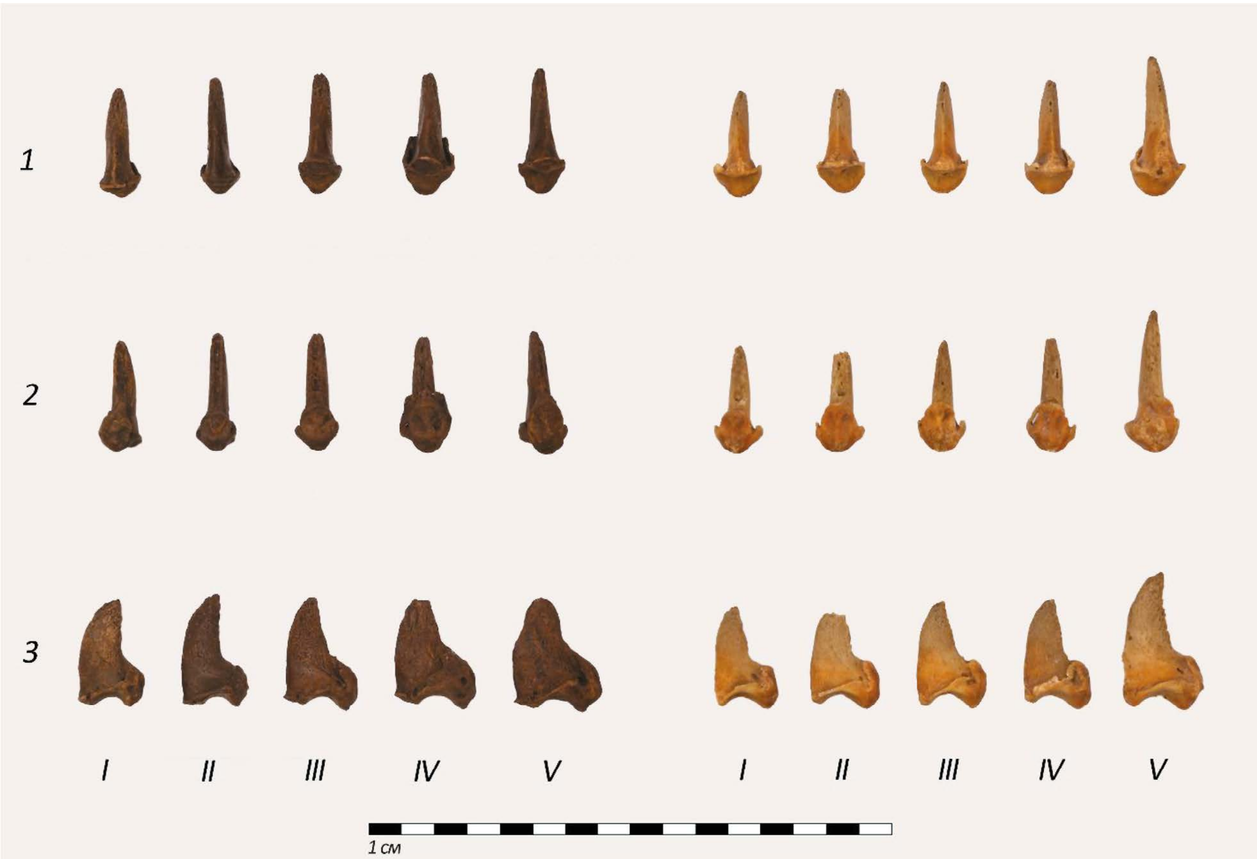

Fig. 12. Distal phalanges of bear hand and bear foot. From top to bottom: dorsal view, palmar view, lateral view.

Fig. 13. Proximal sesamoids from bear hand and foot. The rightmost bone is the sesamoid from the anterior tibial muscle ligament.

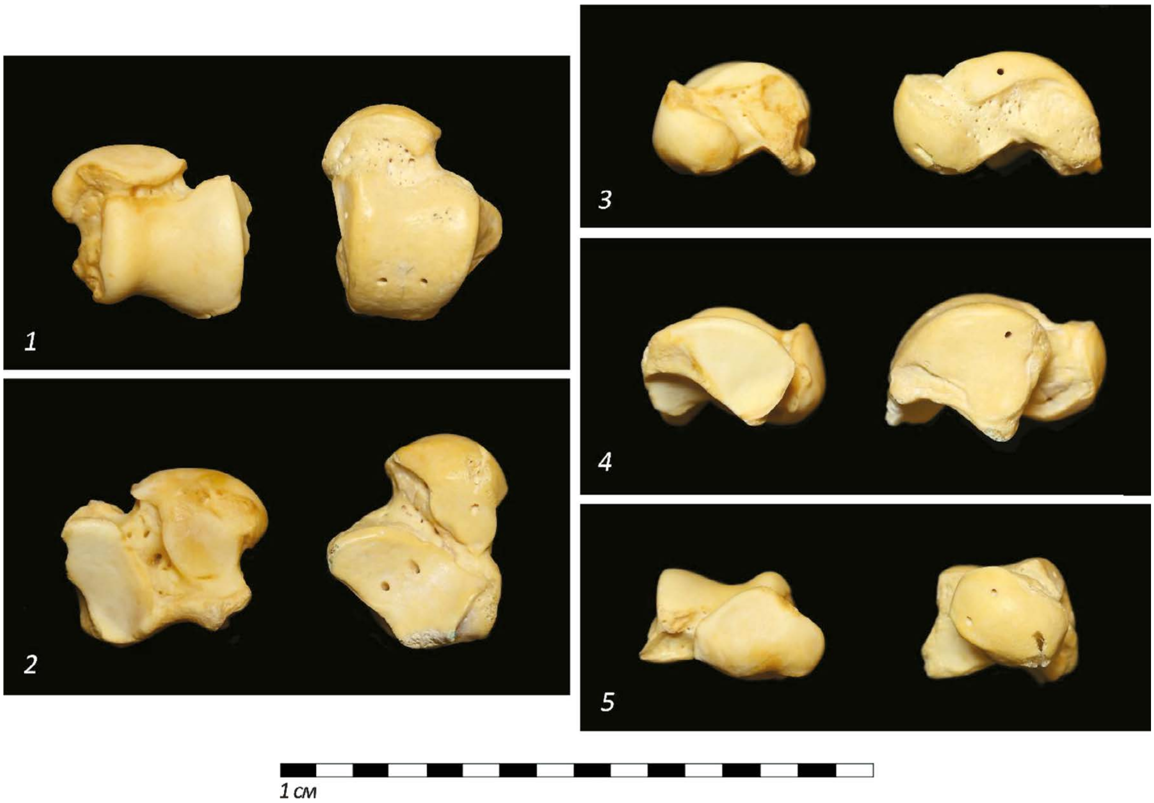

Fig. 14. Bear talus and human talus: *1* — dorsal view; *2* — plantar view; *3* — medial view; *4* — lateral view; *5* — distal view.

Compared to the human talus, the bear's talus is broad and short, exhibiting a pronounced concave block shape, shorter neck, and triangular-shaped head.

The heel bone (*calcaneus*) is the largest bone of the distal part of the bear's pelvic limb. It distinguishes the body from the calcaneal tubercle (Fig. 15).

In the medial aspect of the calcaneus, the talus support is the most prominent feature, bearing a groove on its plantar surface for the tendon of the deep toe flexor. The anterior surface of the calcaneus is characterized by a saddle-shaped cuboidal articular surface for contact with the corresponding bone. Below this surface, a groove for the tendon of the tibialis minor longus muscle is present.

The posterior articular surface of the talus is located above the calcaneus, proximal to the middle of the calcaneus' body. The anterior articular surface of the talus is situated on the medial side of the calcaneus and separated from the posterior articular surface by the calcaneal sulcus.

The talus and calcaneal sulcus junction forms the tarsal sinus, through which the tarsal canal passes.

The anatomy of the bear's heel bone differs from that of the human heel bone. The bear's heel bone is elongated anteroposteriorly, tapers toward the middle, and has a less pronounced calcaneal tubercle. Furthermore, the shapes of the articular surfaces differ, particularly the posterior one. In bears, this surface is oval and elongated, whereas

Fig. 15. Bear calcaneus and human calcaneus: *1* — distal view; *2* — medial view; *3* — dorsal view; *4* — lateral view.

in humans, it is more rounded. A notable distinction is the development of the peroneal block in bears, which is a spur that protrudes laterally from the body of the heel bone with a downward bend. The tendon furrow of the long peroneal muscle passes under the block.

The scaphoid (*os naviculare*) is flattened anteriorly (Fig. 16) and situated between the head of the talus and cuboid and cuneiform bones. Its posterior concave articular surface connects it to the talus head. The anterior part of the bone (distal part) is occupied by three articular facets for the cuneiform bones with barely distinguishable borders, which collectively constitute almost the entire anterior surface of the bone. The lateral facet is represented by a straight-cut edge and bears a narrow articular surface for the cuboid bone. A rough tubercle protrudes medially and downwards, and the other surfaces are occupied by the tuberosity of the scaphoid for ligament fixation.

The bear's scaphoid is thinner, and its oval shape is characterized by a sharply abrupt lateral margin. The rough tubercle of the scaphoid of the bear is less developed, and the tuberosity on the extra-articular surfaces has sharp protruding jagged edges.

Cuneiform bones (*ossa cuneiformia*)

The medial cuneiform bone (*os cuneiforme mediale*) is the second largest tarsal cuneiform bone (Fig. 17). On the posterolateral surface, it carries the articular fossa for the scaphoid and intermediate cuneiform bones. The anterior concave articular surface of the medial cuneiform bone connects with the first metatarsal bone.

The bear's medial cuneiform bone is approximately half the size of a similar human bone. Additionally, the articular surfaces show differences in shape and location. The anterior articular surface of the bear is concave, with an irregular edge, whereas the human bone has a slightly convex surface and bean-shape profile. The articular surface of the intermediate cuneiform bone in the bear runs parallel to the articular surface of the scaphoid as its extension, occupying slightly less than half of the lateral margin of the bone. In humans, this articular surface merges with the articular surface of the scaphoid for a short distance.

The intermediate cuneiform bone (*os cuneiforme intermedium*) is triangular in shape and flattened anteriorly and posteriorly (Fig. 17, *1*). The bone has articular surfaces on the medial, lateral, distal, and proximal sides, which facilitate contact with the medial and lateral cuneiform, second metatarsal, and scaphoids. The distal and proximal articular surfaces are expansive, and the fossae for the adjacent cuneiform bone attachment are narrow and elongated. The dorsal and plantar sides are rough for the attachment of ligaments. It is the smallest of the cuneiform bones.

Fig. 16. Bear navicular and human navicular: *1* — distal view; *2* — proximal view; *3* — lateral view.

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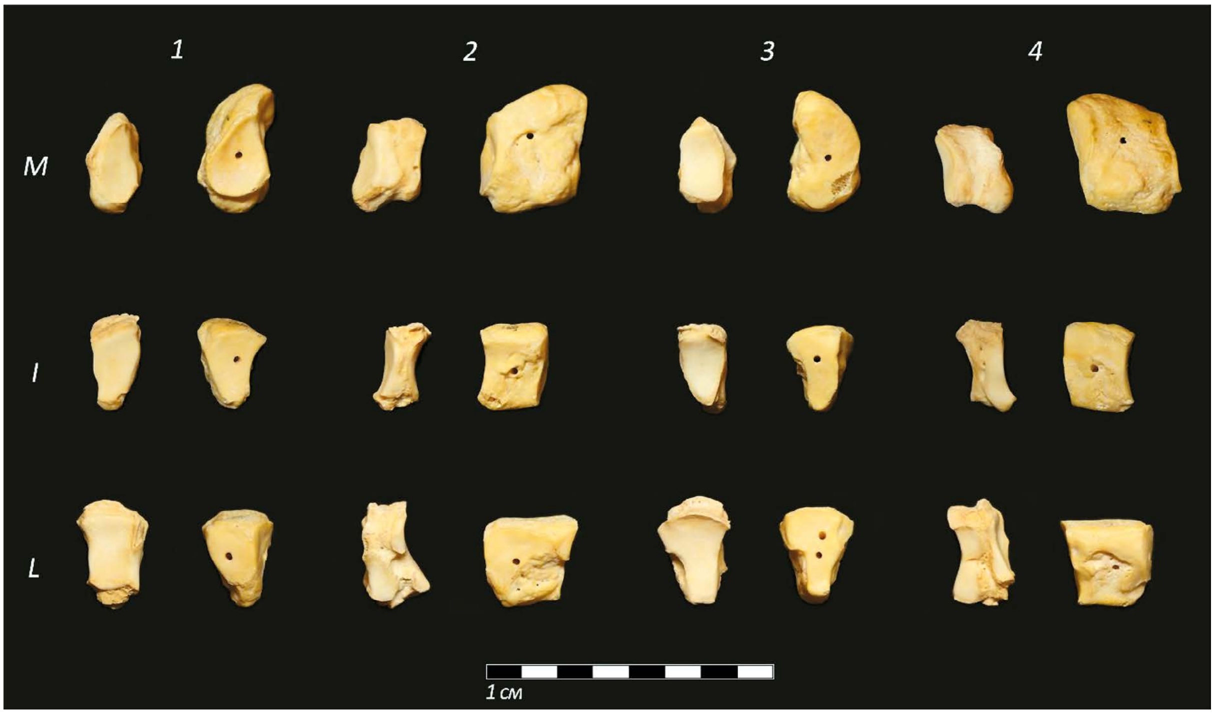

Fig. 17. Bear cuneiforms (left in each pair) and human cuneiforms (right in each pair): *M* — medial cuneiforms; *I* — intermediate cuneiforms; *L* — lateral cuneiforms; *1* — proximal view; *2* — lateral view; *3* — distal view; *4* — medial view.

The intermediate cuneiform bone of the bear is approximately half the size of its human counterpart. Notably, despite this discrepancy in size, a striking similarity is noted in overall shape, particularly when the human bone is considered to be thicker anteroposteriorly. The proximal articular surfaces of both bones are concave and triangular in shape, whereas the distal articular surface is concave in the bear and slightly convex in the human.

The lateral cuneiform bone (*os cuneiforme laterale*) is triangular and flattened anteriorly (Fig. 17, *L*). It is the largest of the cuneiform bones in bears. A triangular concave articular surface connects distally with the third metatarsal bone. Medially, two articular fossae, connected by a thin bridge, articulate with the second metatarsal bone, and a narrow articular surface articulates with the intermediate cuneiform bone. Laterally, it articulates with the cuboid bone, and proximally, the slightly concave square articular surface adjoins the scaphoid. On the dorsal and plantar sides, there are rough surfaces for ligament attachment.

The thickness of bear bone is approximately twice that of human bone in anteroposterior measurements. The proximal articular surface of the bear bone has a slight concave and rectangular configuration, and the human bone displays an oval and flattened morphology.

The cuboid bone (*os cuboideum*) is situated between the calcaneus, talus, scaphoid, lateral cuneiform, and fourth and fifth metatarsals. Proximally, it features a convex articular surface for contact with the calcaneus and a small, slightly concave triangular fossa for articulation with the talus head (Fig. 18). The dorsolateral aspect of the bone shows a narrow strip of extra-articular surface, whereas the plantar aspect displays the tuberosity of the cuboid bone. This is flanked by the tendon groove of the peroneus longus muscle. Medially, the bone presents a narrow elongated articular surface for the scaphoid and several fossae for the lateral cuneiform bone. The distal edge displays a slightly concave articular surface in the center for the fourth and fifth metatarsals.

The cuboid bone of the bear, comparable to all bones of the distal tarsal row, is flattened anteroposteriorly, resulting in inadequate wide extra-articular surfaces compared to the human cuboid bone. The cuboid bone of the bear is distinct from the human cuboid bone in that it is connected to the talus head. The heel articular surface of the bear is convex, whereas in humans, it is convex/concave with a protruding pointed part. The cuboidal tuberosity is more pronounced in the bear.

The metatarsal bones (*ossa metatarsalia*) resemble the metacarpals of the thoracic limb, but exhibit a more distinguished morphology. They comprise five tubular bones, with the first metatarsal bone being the shortest and thinnest and the fourth and fifth metatarsal bones being the largest (Fig. 19).

The metatarsal bones are indicated by extensive bases that exhibit articular surfaces for connection to each other and the tarsal bones. The plantar surfaces of the metatarsal bone bases exhibit a tuberosity. On the fifth metatarsal bone, the tuberosity extends to the lateral side of the base in the form of a protruding tubercle. In the existing literature, the tuberosity is only noted on the first and fifth metatarsal bones. However, our observations show that it is present on all plantar surfaces of the bases, with varying degrees of development.

The distal epiphyses of the metatarsal bones are represented by block-shaped heads. Each head is

1 см

Fig. 18. Bear cuboid and human cuboid: *1* — dorsal view; *2* — medial view; *3* — distal view; *4* — lateral view; *5* — proximal view.

characterized by a ridge that originates dorsal surface at the apex and terminates on the plantar surface with a small coracoid process. Two notches are found on the sides of the crest. Two sesamoid bones are located on the plantar surface of each block. Typically, there are 10 proximal sesamoid bones, analogous to the thoracic limb. The number of sesamoid bones from the region of the joint between the middle and distal phalanges is five [15]. Distal sesamoid bones are absent in our preparations.

A notable distinction between the metatarsal bones of the bear and those of the human is a ridge on the heads of the bones. In humans, only the head of the first metatarsal bone exhibits a relief that has resemblance to this structure. The tarsal bones of bears are manifested by their substantial relief, a structure of lateral articular surfaces, and a fixation mechanism that allows them to be held in a tightly fixed position relative to each other. This is particularly evident in rays III–V.

The finger bones (*ossa digitorum*) of the pelvic limb of the bear show all the characteristics of the phalanges of the hand, excluding the length and mass. The phalanges of the foot are shorter and thinner than those of the hand. However, the literature reveals an opposite pattern [15]. These indices may vary.

The proximal phalanges (*phalanx proximalis*) of the bear's foot has a closer resemblance to the phalanges of the human hand (Fig. 20). They are significantly larger, flattened in the dorsopalmar direction, and exhibit a consistent width with the length of the body. At the base, they possess a semilunar fossa that is not rounded, as observed in humans, and a more pronounced sulcus of the block.

The middle phalanges (*phalanx media*) of the bear's foot are larger than the middle phalanges of the human foot (Fig. 20). The ridges of the bases are more pronounced and extend dorsally into the extensor digits. Palmarly, a distinct flexor roughness can be observed just behind the crest.

The distal phalanges (*phalanx distalis*) of the foot, similar to the distal phalanges of the hand, terminate in a claw-like process rather than a tuberosity, which is the typical morphology observed in humans (Fig. 20).

The shape, number, and location of the main sesamoid bones of the foot are identical to those of the thoracic limb (Fig. 13). The sole exception is the sesamoid bone embedded in the tendon of the tibialis anterior muscle. This bone is irregularly shaped, has a convex articular surface on the lateral side, and is located medial to the scaphoid and medial cuneiform bone junction.

DISCUSSION

The structural similarity between the hand and foot bones of bears and humans is due to the unique characteristics of their locomotion. Bears are distinguished by their ability to walk on their feet, a movement that involves the entire foot [17].

The bear's stance exhibits distinctive characteristics. The load and functions comparable to those of the human heel bone fall on the proximal part of the metatarsal bones. The true heel, which includes the tarsal and heel bones, maintains a constant angle relative to the surface and is rarely imprinted in the footprint. The obliquity of the bear, which is an adaptation that enables the animal to maintain balance with a heavy body, allows the fulcrum to be brought closer to the midline of the body. Moreover, the hind legs have a larger support area than the front legs, which are more often involved in manipulating objects and climbing trees, because the load on the hind limbs increases during such movements. Interestingly, the forelimbs retain great importance during running, making stronger thrusts [18].

These features account for the significant differences in the skeletal structure of the distal limbs of bears, which contribute to overall strengthening and reduced joint

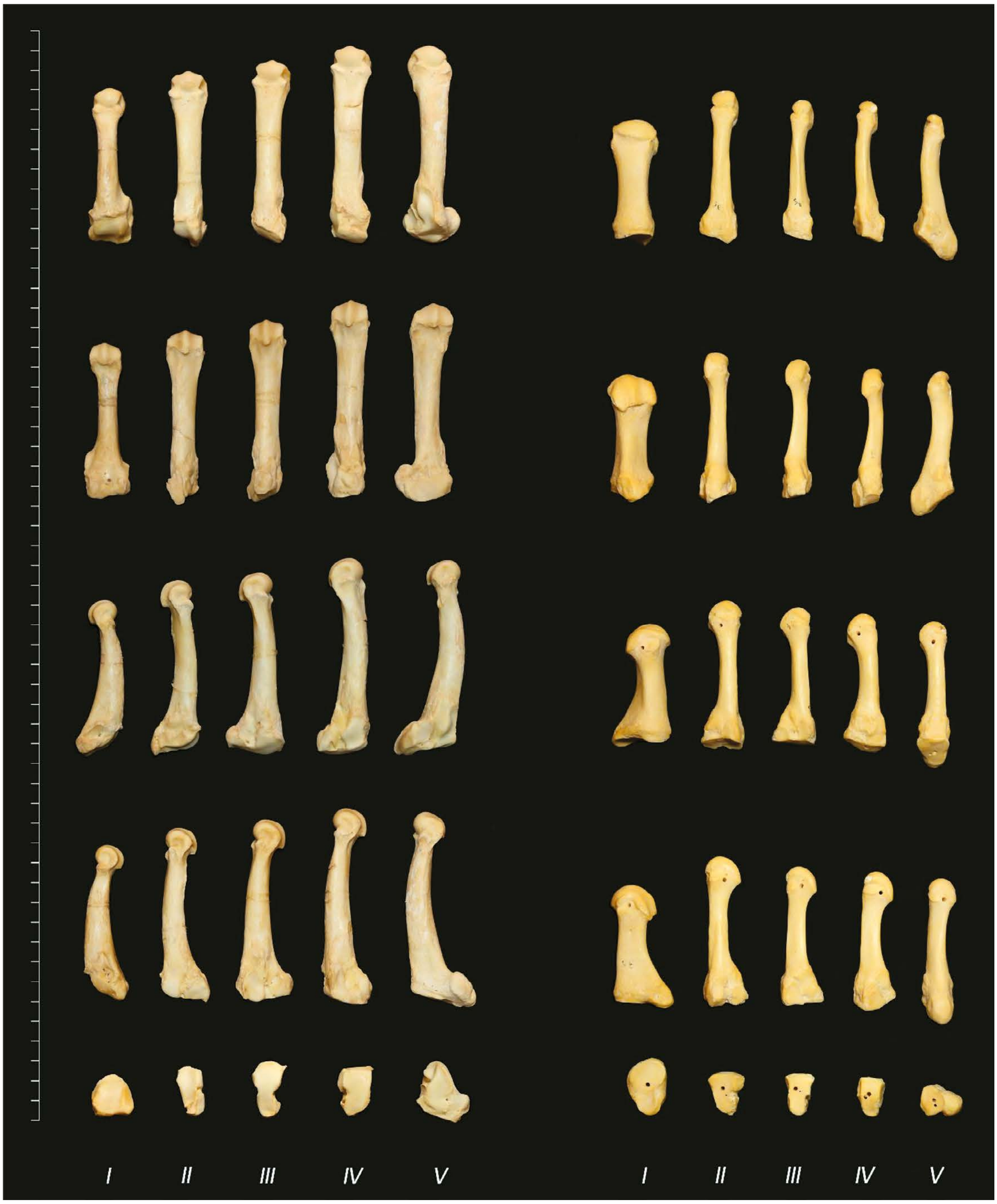

Fig. 19. Bear metatarsals and human metatarsals. From top to bottom: dorsal view, plantar view, medial view, lateral view. Scale ruler segment — 1 cm.

mobility. The bear's hand is comparable in size to the foot and is less functional than the human hand, which results in the bones of the hand differing more from the human hand in size and morphology. Conversely, the foot is different: all the bones of the bear's foot have direct analogs in the human foot and are closer to them in size, which makes it difficult to determine.

Features of the carpal bones of the bear:

- The fusion of the scapholunate [9] ensured the strengthening of the wrist.
- The large, distantly resembling the metacarpal or phalanx, the pisiform bone of the wrist creates a large area for the attachment of the musculo-ligamentous apparatus and forms a joint with the ulnar bone of the forearm. In the hand, this bone causes the main difficulties. Researchers either ignore [12] or erroneously write about its fusion with the triangular bone [9].

Features of the tarsal bones of the bear:

- The body of the bear's heel bone narrows medially and has a large peroneal block on the lateral surface.
- The talus block is more pronounced [2], and the width of the bone exceeds its length [1].
- The largest cuneiform tarsal bone is the lateral one, reflecting the general thickening of the entire lateral edge of the foot.

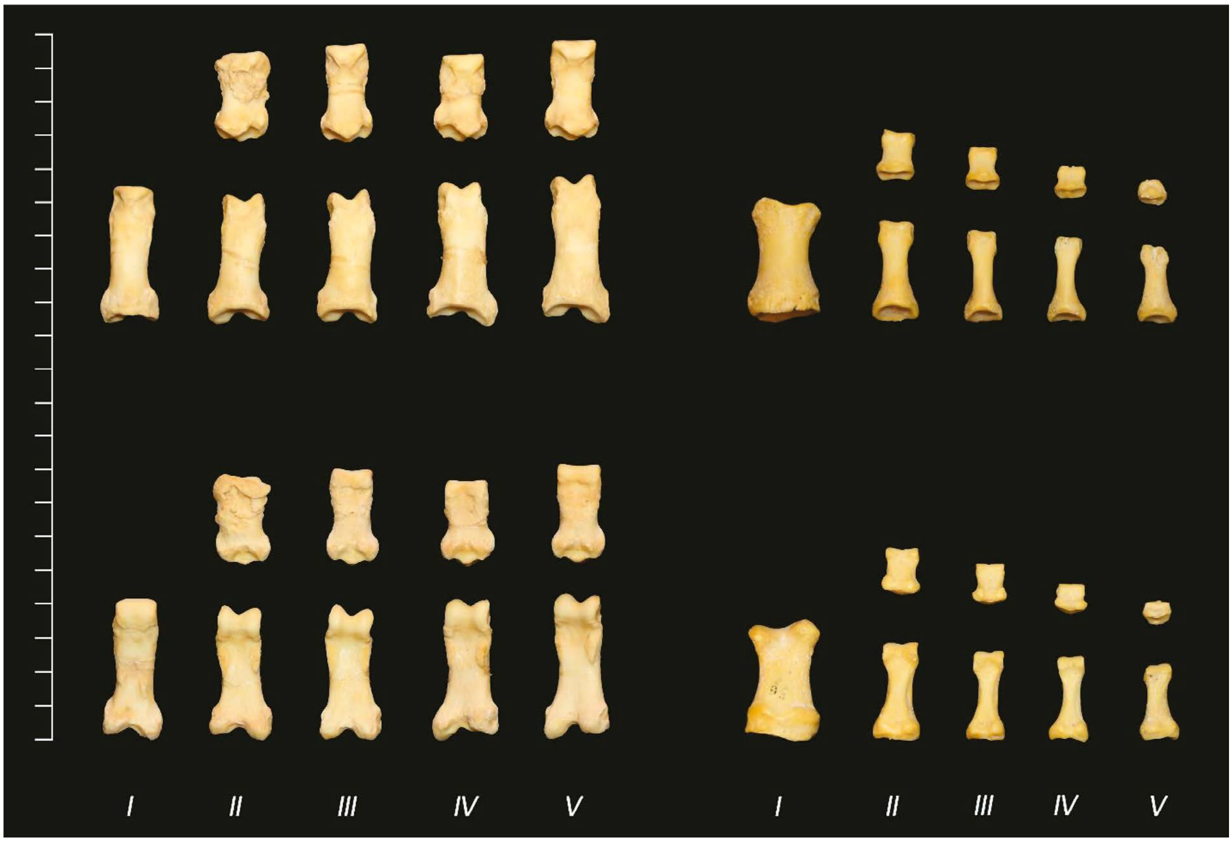

Fig. 20. Bear proximal and intermediate foot phalanges and human proximal and intermediate foot phalanges. Scale ruler segment — 1 cm. From top to bottom: dorsal view, plantar view.

- Flattening in the anteroposterior direction of the tarsal bones, excluding the calcaneus [1].

Features of the metacarpal, metatarsal, and phalangeal bones of the bear:

- An increase in the size and massiveness of the metacarpal and metatarsal bones from I to V, which makes the bear's paw a mirror image of the distal parts of the human limbs. Some studies noted this regularity for the phalanges of the fingers [2]; however, it was not confirmed in our material.
- Presence of a ridge on the heads of the metacarpal and metatarsal bones [6, 7, 19].
- Large number of sesamoid bones present [2, 15, 20].
- The heads of the proximal phalanges of the hand and foot have a V-shaped groove. In humans, this articular surface has a relatively smooth flat shape [2, 12].
- Presence of a claw-like process on the distal phalanges.

CONCLUSIONS

Comparative anatomical analysis revealed similarities in the structure of the bones of the hand and foot of brown bears and humans, which can be attributed to the evolution of foot walking. This complicates the determination of the remains' belonging, as dimensional characteristics are an inaccurate criterion. The identification of scattered bones raises several questions.

The characteristics of bear bones described in the present study, when combined with illustrative material, are beneficial in identifying individual bones of the distal limbs and their fragments.

ADDITIONAL INFORMATION

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