**Supplementary data**

**Methods**:

The whole specimen was scanned at IVPP using a micro-CT scanner with a resolution of 51.75 microns, under scanning parameters of Voltage 140 kv, current 120 mA. Individual bony elements were identified and segmented in Avizo 9.0 (Thermo Fisher Scientific). Individual bones were manually segmented based on the contrast of bone versus the surrounding mudstone matrix. Measurements were taken using a digital caliper to 0.01 mm, but rounded to the nearest 0.1 mm and nearest mm (see Tables 1-2), and also taken from the rendering of 3D reconstruction in Avizo 9.0 (Thermo Fisher Scientific).

Material examined (IVPP – Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China; USNM – United States National Museum Ornithology Collection, Washington D.C., USA):

*Syrrhaptes* *paradoxus* IVPP OV 529, IVPP OV 973, USNM 621505; *Pterocles* *namaqua* USNM 642431; *P*. *senegallus* USNM 641935; *P*. *bicinctus* USNM 429081; *P*. *decoratus* USNM 636741; *P*. *burchelli* USNM 430845 and 430631; *P*. *gutteralis* USNM 488869; *P*. *orientalis* USNM 344845 and 18850; and *P*. *alchata* USNM 645835.

**Extended Diagnosis**

The fossil shares many characters with Columbidae and Pteroclidae (Columbiformes) including the cranially projecting triangular shape of the deltopectoral crest, the rim of the pneumotricipital fossa that undulates with a ventral (proximally directed) concavity to its margin, a humeral dorsal tubercle flush with the shaft, the procoracoid process lacking a foramen (for n. supracoracoidei), large sternal articulation facets on the coracoid, a large inflated acrocoracoid with a medial hook, and a proximally positioned dorsal supracondylar tubercle on the humerus, in addition to much of the general morphology of the fossil skeleton [1; 2]. The fossil has a concave scapular cotyle, a relatively short coracoid shaft, and the pneumatic pocket within the impression of m. sterncoracoidei is on the lateral aspect (rather than medial), and those features are shared with extant Pteroclidae, not Columbidae. Other features of the skeleton including the elongate dorsal supracondylar process of the humerus, absence of a distinct olecranon fossa on the humerus, and an elongate contact surface on the furcula for the acrocoracoid further help to differentiate the fossil from Columbidae. The fossil differs from *Syrrhaptes* in being slightly larger, having a much less distinct groove for the tendon of m. ulnometacarpalis ventralis on the radiale, having a foramen or pit in the m. supracoracoideus fossa on the caudal face of the acrocoracoid, and the attachment site of the m. gastrocnemius on the distal femur is flush with the adjacent bone surface (rather than being elevated).

*Linxiavis* *inaquosus* is much smaller (see supplementary Table 1 for measurements) than the extinct *Archaeoganga* *pinguis* (coracoid ~46 mm long), *A*. *validus* (~37 mm long), and *Leptoganga* *sepultus* (~30 mm long) [3]. It is similar in size to *A.* *larvatus* (coracoid length ~26 mm), but specimens of *Archaeoganga* and *Leptoganga* have a longer coracoid shaft (where the medial and lateral margins of the shaft, the area sternal to the scapular cotyle, are parallel or subparallel) than that of *Linxiavis* and extant sandgrouse.

A potential unique apomorphy of this new taxon is the shape of the ventral cotyle of the ulna with its straight dorsal margins (rather than rounded) that form an obtuse angle. The dorsocaudally elongate omal end of the furcula with a pointed apex in its dorsal side (rather than squared off or a broad rounded end) also may be an autapomorphy, given its absence in *Syrrhaptes*, the species of *Pterocles* examined, and columbids.

**Extended description and comparisons**:

The fractured left humerus is missing the distal end, and is largely obscured by sediment. The only morphological feature visible on the left side is a part of the transverse ligamental groove. The right humerus is quite complete (Figures 2 and 3). The humeral head projects distinctly proximally. The deltopectoral crest is subtriangular in outline with a tubercular apex located just distal to the proximodistal level of the transverse ligamental groove. The deltopectoral crest of the fossil and *Syrrhaptes* do not have a raised area for muscle insertion on the cranial/ventral face, but the scar in *Columba* is slightly raised. The pneumotricipital fossa is partially closed by a bony wall perforated by foramina. The ventral rim of the pneumotricipital fossa is expanded as in *Syrrhaptes*, but it appears that there are no pneumatic foramina on the expanded rim in the fossil (unlike *Syrrhaptes*). However, the surface is irregular with small pits that might be pneumatic in origin. The expanded rim is undulatory with multiple foramina in *Syrrhaptes*, and the foramina are absent in *Columba*. The dorsal crus of the pneumotricipital fossa is short and oriented more dorsoventrally. There is a distinct m. scapulotriceps groove on the distal end, but the ventral rim of the groove is broken away. It appears that the ventral rim of the m. scapulotriceps groove may have been a broader process than the proximodistally elongate process in *Syrrhaptes*. The flexor process is broken away, but it appears that the flexor process and dorsal condyle extended approximately to the same distal level. However, the ventral condyle extends distal to both the dorsal condyle and flexor process. There is no distinct olecranon fossa on the specimen. The area where it would be is shallowly concave. The absence of a distinct fossa is shared with *Syrrhaptes*, and *Columba* has a distinct fossa that cuts into the ventral condyle and base of the flexor process. The dorsal supracondylar tubercle is proximodistally elongate (not a rounded tubercle) and located far proximally (proximal even to the level of the proximal end of the flexor process’s base). The dorsal supracondylar tubercle is rounded in *Columba* and elongate in *Syrrhaptes*, like the fossil. The facet for the ventral collateral ligament faces cranially and is not deflected distally or ventrally. The ventral part of the brachial fossa appears to be the deepest portion.

The articulated approximately distal two-thirds of the left radius and ulna lie above the proximal left humerus. Both are fractured in several places, and there are a few small feather papillae preserved on the left ulnar shaft. The dorsal condyle of the left ulna is visible in dorsal view, and there is a dorsal short ridge at the distal end adjacent to a shallow ligamental groove. The distal end of the right ulna preserves a short blunt carpal tubercle. The short blunt carpal tubercle is shared with *Syrrhaptes*, and the carpal tubercle in *Columba* is more elongate and has a notch between it and the distal condyle in the distal margin. No papillae are visible on the right ulnar shaft. The right ulna preserves the proximal end of the bone. The olecranon process is elongate craniocaudally (not rounded). The elongate morphology is shared with *Syrrhaptes*, and contrasts with the larger rounded morphology in *Columba*. The outline of the ventral cotyle is roughly diamond shaped, but that is in part the result of the loss of bone on the ventral aspect of the cotyle. However, the straight obtuse angled dorsal margin of the ventral cotyle appears to not be an artifact. In *Syrrhaptes*, the dorsal margin of the cotyle is curved and the entire cotyle has a subcircular outline. In *Columba*, the ventral margin is straight and the dorsal margin is a wide arch. The dorsal cotyle projects cranially extending cranial to the ventral cotyle with its apex at the cotyle’s dorsal edge. The area caudal to the dorsal cotyle and dorsal to the olecranon process is concave. Much of the proximal ventral surface of the right ulna is covered by another avian long bone that may be a portion of the shaft of the tibiotarsus or femur. The ulnar shaft has a slight curve to it, and it is fractured with pieces of bone missing. The ulna is longer than the humerus (supplementary Table 1).

It appears that the shaft of the radius was straighter than the curved shaft of the ulna. The distal end of the left radius preserves a concave area for the tendinal sulcus. The right radius is missing its distal end and the proximal end is largely obscured by the humerus and ulna, where it is still in contact with the dorsal condyle of the humerus. However, a small fossa on the ventral side of the proximal end of the right radius is visible, and that concavity appears to be enhanced by some bone loss in the same area.

The left radiale is in contact with the ulna, radius, and carpometacarpus, but the right radiale appears to be missing. In distal view, the radiale is roughly trapezoidal in outline with the narrow side on the dorsal aspect (supplementary Figure 1). It appears that the ventral tip of the radiale is chipped. The ridge cranially adjacent to the articular face for the radius is a continuous ridge that does not extend to the ventral end of the bone. This differs from Columbidae where the ridge is divided into two concave sections for the passage of the tendons of the m. extensor carpi radialis and m. extensor longus alulae [4]. The fossil differs from *Syrrhaptes* in that the ridge cranially adjacent to the articular facet for the radius does not extend to the dorsal and ventral ends of the bone (in *Syrrhaptes* and *Columba*), being positioned more in the dorsoventral middle of the edge of the bone. The fossil also has a much less distinct notch for the tendon of the m. ulnometacarpalis ventralis than that in *Syrrhaptes* and Columbidae [4] because the ventral margin is relatively straighter in the fossil.

The left ulnare is preserved and it is positioned in between the distal ulna and the missing carpal trochlea of the carpometacarpus (Figures 2 and 3). A fragment of bone in between the minor metacarpal of the right carpometacarpus and the distal right ulna might be the remnants of the right ulnare. The ulnare has a long dorsal crus, slightly longer than the short crus (Figure 2). The metacarpal incisure is relatively shallow but wide (Figure 3), and the margin of the ulnare opposite the incisure is slightly concave, this incisure shape is most similar to that of *P. gutturalis*, *P. namaqua,* and *P. burchelli* **(**Supplementary figure 1**)**. The tubercle on the proximal end at the base of the long crus is broken away in the fossil. The margin of the bone along the long crus is relatively straight in the fossil, but that same margin is curved in *Syrrhaptes*. The ulnare in *Columba* is much more asymmetric with the long crus much longer than the short crus, and the proximal margin is not straight like the fossil.

The left carpometacarpus is missing much of the carpal trochlea including the fornix. Part of the extensor process and dorsal surface also are missing. The alular facet appears to be preserved and a flattened fragment of bone adjacent to the extensor process may be part of the alular phalanx. Most of the right carpometacarpus is missing with only part of the major and minor metacarpals are present, but they do not preserve any significant morphology. The preserved surface of the proximal end of the left carpometacarpus is concave. A large chip of the proximal major metacarpal distal to the fragment of alular phalanx is missing, and that is where a small intermetacarpal process would be positioned if present in life. The preserved portion of the right major metacarpal does not appear to preserve an intermetacarpal process. *Syrrhaptes* has a small intermetacarpal process, and *Columba* lacks one. The major metacarpal has a dorsally concave area for the passage of a tendon only at its distal end. Only parts of the minor metacarpal are preserved, and as preserved it appears that the intermetacarpal space widened distally. The shape of the intermetacarpal space differs slightly between the left and right sides, with the right side preserving a more undulatory shape of the minor metacarpal shaft. The distal end of the intermetacarpal space is narrower in the fossil than the more broad, rounded margin in *Syrrhaptes*. The fossil lacks a tendinal groove along much of the dorsal aspect of the major metacarpal like the state present in *Syrrhaptes*. It also appears that the relative difference in size between the proximal and distal widths of the intermetacarpal space of the fossil is greater than that in *Syrrhaptes*. The concave proximal facet of the minor digit phalanx is preserved, but most of the rest of the phalanx is missing. The proximal phalanx of the right major digit is covered by sediment and the overlying remnants of the carpometacarpus. The proximal phalanx of the left major digit has a small process on the cranial proximal base of the phalanx. There are two foramina near the center of the large phalanx. The flattened caudal portion of the phalanx is incomplete with its end worn away, and the flattened portion extends distal to the distal articular facet. The distal phalanx of the major digit has a concave face on its dorsocaudal proximal base. The distal part of the distal phalanx is missing. The distal phalanx has a small cranial process on the proximal end of its cranial face (in the ventral half of the phalanx). The phalanges are similar to that of *Syrrhaptes* with their processes and foramina. *Columba* lacks foramina in the major digit phalanx.

The furcula is preserved. There does not appear to have been a distinct hypocleideum or expansion near the synostosis of the furcular rami, although there appears to be some bone loss in the area. The synostosis is pressed against the sternal end of the right coracoid. The ventral portion of the furcula and rami are flattened craniocaudally. The rami expand in their craniocaudal width dorsally. The rami are craniocaudally wider than the state in *Columba* which are narrow along their length. The right ramus is still in contact with the acrocoracoid. The articular surface of the furcula is more craniocaudally elongate (offset from the dorsoventrally oriented ramus), and it comes to a rounded dorsocaudally directed apex with a flattened medial surface. The furcula in *Columba* does not have the caudally directed and elongated contact with the acrocoracoid like the fossil. *Pterocles* *decoratus* does have an elongate contact, but with a squared off rather than rounded apex.

The right coracoid is preserved. It is missing the lateral sternal corner, but the rest of the sternal end is present. The medial angle (tip) of the sternal articulation is broken away (Figure 3). The preserved medial portion of the sternal articulation has two distinct articulation surfaces at an angle to one another; a wider and rounder ventral articulation and a mediolaterally wide (but dorsoventrally narrow) facet on the dorsal aspect. The medial ventral facet faces more ventrally than the state in *Syrrhaptes*. The humeral articular facet is nearly flat and projects laterally away from the shaft. The acrocoracoid is missing its ventral tip, and it cannot be determined if the ventral aspect of the acrocoracoid was hooked (as in *Syrrhaptes*). The cranial face of the acrocoracoid is mostly occupied by the relatively large scar for the acrocoracohumeralis ligament. The ventral tip of the acrocoracoid (the bicipital tubercle) has a concave pit for muscular attachment. It appears that there is a pneumatic foramen (or at least a deep pit) in the m. supracoracoideus fossa on the caudal face of the acrocoracoid underneath the facet for the furcula. *Syrrhaptes* has no foramen in the m. supracoracoideus fossa. Based on the CT-scan (Figure 3), there is no foramen for the n. supracoracoidei (i.e. procoracoid foramen), and the procoracoid process is short (but could be broken or not rendering properly in the CT imagery).

The right scapula is preserved in articulation with the coracoid. The scapular blade lies alongside the notarium and on top of the bovid skull fragment (Figure 2). The distal blade is as wide or even wider than the proximal shaft, and was very long, extending caudally to near the cranial end of the synsacrum. The acromion process is long and projects dorsally, and cranial end of the bone is quite similar to that of *P. bicinctus* (Figures 3 and 4)*.*

Only a fragment of the distal left femur is preserved, with the lateral condyle exposed. The distal face of the medial condyle is damaged (Figure 2). The tibiofibularis crest is rather short, and the tubercle likely for the m. gastrocnemius lateralis is positioned distally and is not elevated relative to adjacent areas of the bone (supplementary Figure). That muscular tubercle is raised up in *Syrrhaptes* and *Columba*, and the lateral margin of the distal end of the bone (lateral condyle) is more convex in *Syrrhaptes* than that the straighter margin in the fossil and *Columba*.

Adjacent to the medial edge of the femoral fragment, there are two bone fragments with one significantly wider than the other. These two fragments likely are the proximal ends of the left tibiotarsus and fibula missing their proximal surfaces (Figure 2). No identifiable morphological features are preserved such as the cnemial crests or any muscular attachments. The fibula is positioned quite close to the tibiotarsus with a small proximal interosseus foramen. The proximal interosseus foramen is wider in *Syrrhaptes*, and narrow in the fossil and *Columba*.

Adjacent to the proximal tibiotarsus fragment is a free thoracic vertebral centrum. That centrum has a rounded ventral face lacking any crest (Figure 2). In *Columba*, that vertebra is less rounded ventrally coming to a blunt ventral crest. The cranial and caudal articular surfaces are damaged and the transverse processes are missing. That vertebra lacking a ventral keel is consistent with the most caudal free thoracic vertebra in *Syrrhaptes*. In *Syrrhaptes*, the notarium articulates with that vertebra (which in turn articulates caudally with the synsacrum). Cranial to the rounded centrum is a set of fused and broken vertebrae with distinct thin ventral keels. That series of bony fragments extends for approximately the length of four vertebral centra (as in the four vertebrae forming the notarium in Pteroclidae and Columbidae). The scapular blade is positioned alongside the notarium and is in contact with the bovid skull fragment.

**Figure caption.**

Supplementary Figure 1. Enlarged photographs highlighting diagnostic features of *Linxiavis* *inaquosus* (IVPP V24116) A. left manual phalanges in ventral view. B. articulation of the acrocoracoid and furcula in oblique medial view. C. the free thoracic vertebra and adjacent leg bone fragments in ventral and caudal views. D. proximal ulna in oblique proximal view. E. ulnare in distal view. F. radiale in cranial view with *Linxiavis* *inaquosus* (left) and *Syrrhaptes* *paradoxus* IVPP OV 529 (right). Abbreviations: ac – acrocoracoid; ap – apex of the furcular articulation with the acrocoracoid; cb – crus breve (short arm); dc – dorsal cotyle; dm – straight obtuse angled dorsal margin of the ventral cotyle; f – foramen; fb – fibula; gc – origin of the m. gastrocnemius; lc – lateral condyle of femur; mc – medial condyle of femur; mdI – major digit phalanx I; mdII – major digit phalanx II; mi – metacarpal incisure; ndI – minor digit phalanx I; ol – olecranon process; r – ridge without a division for the tendons of m. extensor carpi radalis and m. extensor longus alulae; tb – tibiotarsus; tg – tendinal groove for the m. ulnometacarpalis ventralis; v – free thoracic vertebra; vc – ventral cotyle. Scale bars: A-D bar = 5 mm; E-F bar = 2 mm.

**Table 1. Measurements of major elements for the holotype specimens (**IVPP V24116**) in cm.**

|  |  |
| --- | --- |
| Measurements | cm |
| length of humerus | 4.8 |
| humeral distal dorsoventral width | 0.9 |
| length of ulna | 5.2 |
| length of radius | 4.7 |
| length of coracoid | 2.7 |
| length of carpometacarpus | 2.8 |
| length of Digit III-phalanx 1 | 1.3 |

**Table 2. Coracoid and humerus length in crown members of Pteroclidae. Measurements in mm.**

|  |  |  |
| --- | --- | --- |
| Species | Coracoid length | Humerus length |
| *Linxiavis inaquosus* | 27 | 48 |
| *Pterocles namaqua* | 22 | 38 |
| *Pterocles senegallus* | 25 | 42 |
| *Pterocles bicinctus* | – | 41 |
| *Pterocles decoratus* | 24 | – |
| *Pterocles burchelli* | 22 | 39 |
| *Pterocles gutteralis* | 31 | 54 |
| *Pterocles orientalis* | 30 | 52 |
| *Pterocles alchata* | – | 48 |
| *Syrrhaptes paradoxus* | 29 | 45 |

Supplementary References

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