

# A Mosaic Pattern of Scattered Human Remains

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## Abstract

Human skeletal remains were found in a sandy area in the western part of Israel. Owing to their scattered nature, multiple analyses were required to confirm that they belonged to the same individual. The analyses were completed by estimating the age and sex of each bone, if possible, as well as its probable articulation and relative site location. The probable articulation was found to be largely insufficient here owing to low and moderate confidence in the state of the bones that were found and the significant signs of postmortem scavenging. Sex estimation analysis of different aspects of the bones revealed various mixed or “mosaic” results. This case exemplifies a usage of numerous analytical methods in order to relate unduplicated scattered remains, found at a long distance, to a single individual.

## Keywords

Scattered, Anthropology, Scavenging

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## 1. Case Background

In summer 2016, human skeletal remains were found in a sandy area in the western part of Israel. The remains were found on the surface in two groups approximately 70 meters apart. In the southwest portion of the site, the right humerus and right os coxa were found in proximity, whereas the right scapula was found approximately eight meters away. In the northeast portion of the site, the left femur, left tibia, and one lumbar vertebra were found in proximity, whereas the sternum, left os coxa, sacrum, and two lumbar vertebrae were scattered within an 18-meter region. The bones had a rough surface appearance, including cracks in varying degrees of depth and longitudinal cracks on the long bones. The scapula displayed the most advanced weathering level: “Flaking of outer surface, usually associated with cracks; flakes are long and thin with one edge

attached to the bone; crack edge angular; exfoliation started” (Stage 2; according to Behrensmeyer, 1978 stage classification criteria) [1].

## 2. Methods

As mentioned, owing to the scattered nature of the remains, the bones had to be thoroughly analyzed to confirm whether they belonged to the same individual or not. The analysis was completed using the relative location of the bones at the site, probable articulations, as well as the sex, age, and stature estimation for each individual bone. Sex estimation was determined using both morphological and metric methods: os coxa [2] [3] [4], femur, scapula, and humerus [5]. Age was estimated using the following methods: evaluating the extent of degenerative changes in the pubic symphysis [6], the fusion stage for the humeral head, femoral head, sacrum, and epiphyseal fusion of the scapula [7] and vertebrae [8]. Stature was estimated using the maximum length of the femur and tibia [9].

## 3. Results

### 3.1. Sex Estimation

Sex estimation of both os coxa revealed mixed results. Morphologically, the os coxa were relatively small and gracile, which indicated that the individual was most likely female. The greater sciatic notch (broadest and most open (Score 1); according to Buikstra and Ubelaker, 1994 score scale [7]) indicated that the individual was most likely female while the v-shaped sub-pubic angle, the missing ventral arch, and the wide and flat inferior ramus all indicated that the individual was most likely male [4]. However, the scapula also showed mixed sex estimation results. The height of the glenoid fossa (38 mm) indicated that the individual was most likely male, whereas the maximum length of the scapula (160 mm) fell within the overlapping area between the sexes [5] as did the vertical length of the humeral head (45 mm); however, the vertical length of the femoral head (42.5 mm) indicated that the individual was probably female [5].

### 3.2. Biological Age Estimation

Age estimation results for each bone are shown in **Table 1**. The degree of fusion of sacral segments S3-S4 indicated the lower age limit (17 - 4 years) and the

**Table 1.** Age estimation by bone and method.

Bone	Age estimation	Method used
Sacrum	17 - 24 years	Fusion of sacral segments S3-S4 [7] [10]
Os coxa	19 - 34 years	Morphological changes in the pubic symphysis [6]
Scapula	Over 21 years	Fusion of all epiphyses [7]
Vertebrae	17 - 26 years	Fusion of epiphyses [8]
Humerus	Over 23 years	Fusion of the head [7]

morphological changes in the pubic symphysis (19 - 34 years; Stage 2) indicated the upper age limit. A biological age range of 17 - 34 years was estimated, presuming that the remains belong to a single individual.

### 3.3. The Identification Process

To confirm that the remains belong to the same individual, the above sex and age estimation results were used in addition to their relative location, probable articulation, and estimated stature:

### 3.4. Axial Skeleton

- Of the three lumbar vertebrae, only the anatomically fifth (L5) could be ordered. Neither articulation between L5 and the two other lumbar vertebrae, nor between the two other lumbar vertebrae could be confirmed. However, age estimation analysis revealed that all three vertebrae were in the same stage of epiphyseal fusion, indicating a 21 - 22-year-old individual.
- The left articular process of the sacrum and the inferior left articular process of L5 properly articulate. In addition, an overlap in age range was found between the estimated ages of the sacrum (17 - 24 years; S3-S4 partial fusion) and the vertebrae.
- Neither the sternum nor C1 could be confirmed anthropologically as belonging to the same individual; therefore, it was suggested that they be sent for DNA analysis.

### 3.5. Appendicular Skeleton

- The articulation between the head of the humerus and the glenoid fossa of the scapula is insufficient to determine whether the two bones belonged to the same individual [11]. However, metric analysis of the maximum height of the scapula and the maximum height of the humeral head both indicated that they were of indeterminate sex, as were parts of the os coxa.
- The right and left os coxa bones exhibited a similar morphology as well as the same estimated age range, which indicates they most likely belonged to the same individual.
- Proper articulation between the head of the left femur and the left acetabulum can be used with moderate confidence to confirm that these two bones belonged to the same individual [11].
- Proper articulation between the distal aspect of the left femur and the proximal aspect of the left tibia can be used with moderate confidence to confirm that these two bones belonged to the same individual [11]. In addition, the stature estimations for each individual bone were identical (160 - 173 cm).

Owing to the incomplete sacrum, no conclusive articulation analysis of the os coxa bones could be conducted; however, a considerable overlap in age range was found between the bones (**Table 1**). Following the anthropological analysis, the individual's identification was confirmed by DNA analysis. The individual

was a male and 21 years old at the time of his death.

### 3.6. Skeletal Trauma and Taphonomy

The typical remains which may indicate the burial site (ribs and thoracic vertebrae) [12], were not found. Here, the bones of the hands and feet, which are infrequently found [12], were not present. However, the skull, which is found in most cases [12], was also not present. The bones showed no signs of antemortem trauma or diseases; however, most of the bones displayed clear signs of animal scavenging. For example, a spiral fracture was found in the proximal third of the humeral shaft. The fracture margins were the same color as the remainder of the bone, which indicated that the fracture most likely occurred perimortem or immediately postmortem [13] [14]. However, spiral fractures could also result from scavenging, i.e., chewing and trampling [12], signs of which could be seen on most of the bones that were found. Significant areas of the left, right, and inferior aspects of the sacrum showed clear signs of scavenging. Moreover, the vertebrae displayed a loss of the transverse and spinous processes, which is commonly indicative of animal scavenging [12]. Both the scapula and, to a greater degree, the iliac crest showed signs of bite marks. The following scavenging stages are based on which bones were recovered, their state of preservation, articulation, signs of scavenging, and their location at the site. The most likely scavenging stages are described next; however, the time ranges are approximate and dependent on various factors [12]:

Stage 1 (22 days - 2.5 months postmortem): Removal of the articulated right scapula and right humerus.

Stage 2 (2 - 4.5 months postmortem): Removal of the articulated lumbar vertebrae, sacrum, the left os coxa, left femur, and left tibia. It is most likely that at this stage, the right os coxa was also removed and was taken toward the southwestern area (A2). The left os coxa was found without signs of scavenging, which indicates that it was probably hidden or buried for a longer period preceding surface exposure.

## 4. Summary

Two groups of bones were found on the surface of 70 meters apart. Owing to the lack of duplicate bones and similar weathering stages, it is reasonable to assume that the remains belong to a single individual; however, because of the scattered nature of the remains, further analysis was needed for confirmation. The analysis was conducted by estimating the age and sex of each bone, if possible, as well as its probable articulation and relative site location. Probable articulation was found to be largely insufficient in this case due to low and moderate confidence in the bones that were found as well as the prominent and extensive signs of postmortem scavenging. Sex estimation analysis of different aspects of the bones revealed various mixed or “mosaic” results. The mosaic pattern included male, female, overlapping between the sexes, and indeterminate results, both within a single bone, such as the os coxa and the scapula, and between most of the bones:

os coxa, humerus, scapula, and femur. Although some sex estimation techniques of the os coxa suggest that only the morphology of the pubic region be used [5] [15], here the analysis of other areas of the os coxa (e.g. greater sciatic notch, pubis, and ischium) was important in order to relate it to other bones, such as the humerus and scapula. Most of the bones were estimated to be those of a young adult, which attributed the remains to be from a single individual. This case exemplifies a usage of numerous analytical methods in order to relate unduplicated, long-distance scattered remains to a single individual with moderate to high confidence.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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