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Hand Abnormalities in Pygmy Chimpanzees *(Pan paniscus)*

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Abstract. Hand deformities in 2 wild-born pygmy chimpanzees were investigated through dissection, linear measurements, bone mineral analysis and X-rays. Weight of tissue (skin, muscle, bone) was determined for each body segment (hand, forearm, upper arm), permitting comparison between the abnormal and normal upper limbs. In one individual, the right and left forearms and hands differed in tissue weights and bone mineral content. In the other, the hands differed in tissue composition, but not the forearms.

Introduction

A recent report on 96 individuals from three groups of free-ranging pygmy chimpanzees *(Pan paniscus)* at Wamba described a high frequency of finger and toe abnormalities [Kano, 1984]. Most commonly various digits were totally or partially missing, and they appeared severed at joints. In most cases there were no signs of lesions. Almost all the infants and juveniles had completely normal limbs, but all the adult males and half the adult females had one or more limb defects. Therefore Kano concluded that acquired rather than congenital factors accounted for the defects.

In contrast, I report on hand abnormalities in 2 individuals of *Pan paniscus*. The nature of the abnormalities could not have been assessed fully while the animals were alive. However, dissection indicated that the malformations were congenital and not acquired. Findings in this study raise the possibility that among free-ranging *Pan paniscus* populations congenital hand abnormalities may be more common than has been appreciated.

Materials and Methods

In the course of dissecting 2 wild-born pygmy chimpanzees, I discovered that each animal had a malformed hand. Also, when studying 3 pygmy chimpanzee skeletons from the Museum of Comparative Zoology, I noted 1 other abnormal hand. Research on the Tervuren collection of *Pan paniscus* [Zihlman and Cramer, 1978; Susman, 1979] did not reveal similar abnormalities, but only about a dozen of those adult skeletons had intact hand and foot bones.

Lokalema, an old female, was already adult on arrival at Yerkes Primate Center and survived for 5 years. S. Savage-Rumbaugh noted and photographed the left hand with the 2 missing digits (IV and V) on her left hand. We at first suspected that the missing digits were attributable to an old healed injury, although there was no obvious scar present. I dissected the animal fresh frozen at the University of California, Santa Cruz.

Amos, an 11-year old adult male, wild-born pygmy chimp from Zaire, lived in the Ft. Wayne Indiana Zoo after having been a pet. He died of pneumonia, was autopsied and his skin removed. The carcass was stored frozen at the Field Museum of Natural History in Chicago, where I dissected it. In contrast with Lokalema's, Amos's hand abnormalities and the fusion of the III, IV and V metacarpals were not obvious until the dissection of the hand was under way. After Amos' bones were cleaned, I studied them further at the University of California, Santa Cruz.

The adult female pygmy chimp (MCZ 38019) was wild shot from what is now Zaire. As part of a study on pygmy chimp skeletons, I noted and photographed the articulated hand in this individual.

Besides revealing the abnormalities, the methodology developed by Grand [1977] and Zihlman [1984] permitted much more information to be collected. At the time of dissection all tissue (e.g. skin, muscle, bone, fat) within each body segment was weighed. For this study, the relevant segments are the hand, forearm and upper arm. Mineral content of both the right and left radius and ulna was measured with a single-beam photon absorptiometer two-thirds down the shaft on both right and left radius and ulna. This comparative, quantitative approach allows documentation of possible effects of malformations on tissue types other than bone, and on segments other than the affected one.

Table I. Tissue weights: female *Pan paniscus* Lokalema (g)

	Right (normal)	Left (abnormal)
Upper arm segment		
Muscle[1]	415	407
Skin	70	69
Bone[2] (humerus)	216	215
Forearm segment		
Muscle[1]	315	265
Skin	85	81
Bone[2] (radius and ulna)	211	186
Hand segment		
Muscle[1]	39	46
Skin	60	50
Bone[2] (articulated hand)	165	161

[1] The individual was very emaciated at the time of death; therefore muscle weights given here are for relative comparison between right and left sides and not as values for a healthy individual.

[2] All bones were weighed at time of dissection and before cleaning.

Results

Lokalema, Old Adult Female

After dissection, it became clear that on the abnormal left hand the distal and middle phalanges of IV and V were missing entirely; the proximal phalanges were attenuated and resembled distal phalanges. Digit II lacked the entire distal phalanx; the middle phalanx was attenuated and resembled a distal phalanx. Digit III was abnormal in length, curvature and shape. The normal hand is illustrated for comparison with the affected side (fig. 1). The right and left hand segments differed in weight by about 6% (300 vs. 283 g), in length of metacarpals, as well as relative weight of muscle, bone and skin. On the affected left hand, nails were absent on digits I and II, but a nail was present on digit III.

Tissue Composition (table I). In the upper arm segment, tissue weights differed little or not at all. In contrast, the left (abnormal) forearm tissues – muscle, skin, bone – were all lighter than on the right side. For exam-

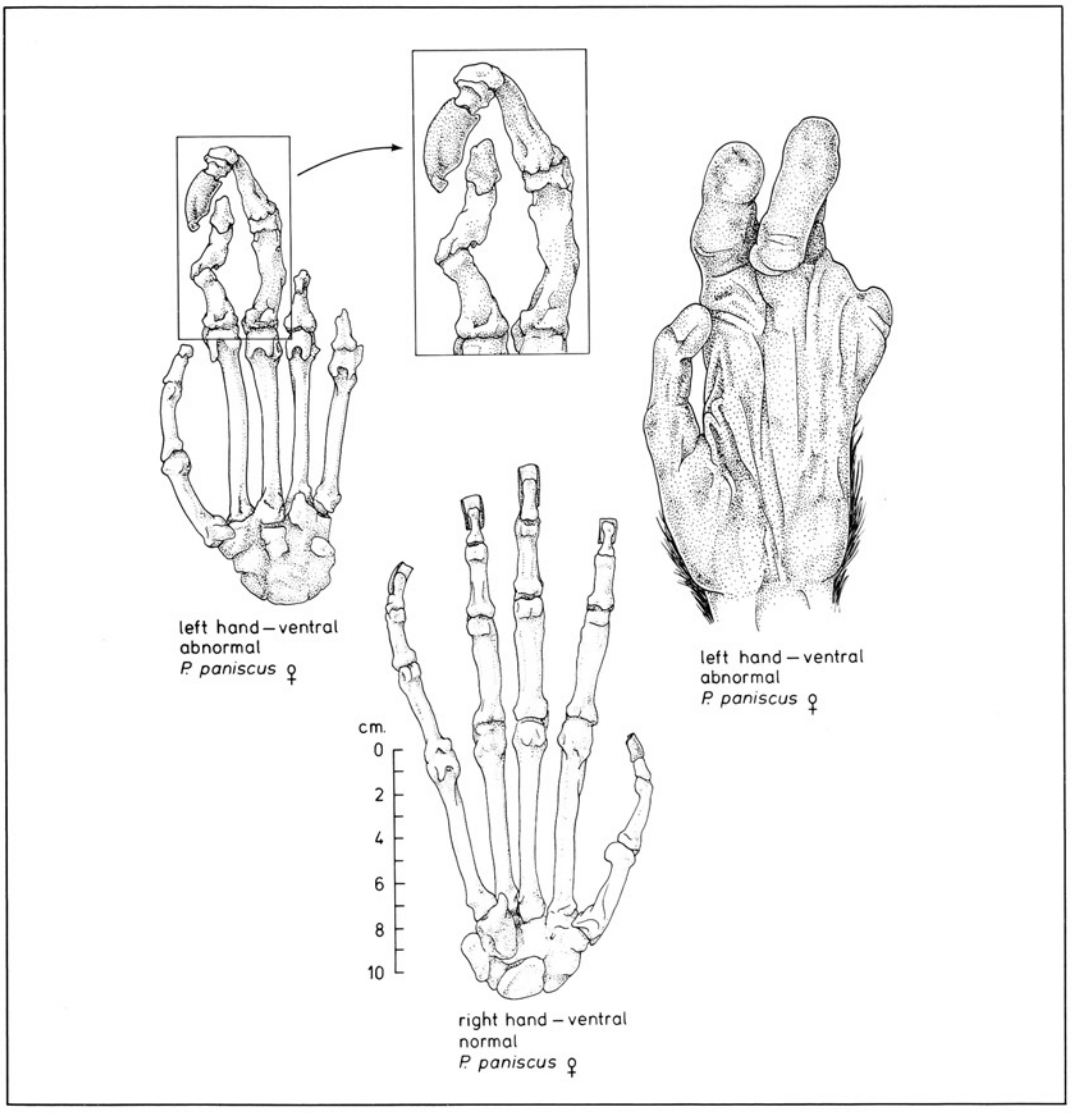

Fig. 1. Normal and abnormal hands of adult female pygmy chimpanzee (Lokalema). Drawn from dissected and partially cleaned, articulated hands.

ple, there was a 17% difference in amount of muscle between right and left sides and a 12.5% difference in bone. The right and left hand segments also differed, but here the muscle mass was heavier in the abnormal (left) side by 16.5%, while skin was about 9% less. Bone weights differed by only 2.6%.

Bone Lengths (table II). The lengths of the humerus, radius and ulna of the right and left sides were nearly identical. In contrast,

all five metacarpals on the abnormal side were longer than those on the right, though the thumb was shorter. Although the abnormal left metacarpal was longer, the proximal and distal phalanges were shorter.

Other Features of the Abnormal Hand (fig. 2). A radiograph revealed a transverse mid-shaft fracture and a fibrous union on the proximal phalanx of digit II. Such a pseudoarthrosis frequently occurs in broken

Table II. Bone lengths: female *Pan paniscus* Lokalema (mm)

	Right (normal)	Left (abnormal)
Humerus	315	312
Radius	291	290
Ulna	299	298
Metacarpal I	42	44
Metacarpal II	97	99
Metacarpal III[1]	97	98
Metacarpal IV	88	89
Metacarpal V	78	79

[1] Mean length for metacarpal III in 6 female *Pan paniscus* = 83 [Susman, 1979].

Table III. Tissue weights: male *Pan paniscus* Amos[1] (g)

	Right (normal)	Left (abnormal)
Upper arm		
Muscle	989	1,008
Bone[2] (humerus)	206	203
Forearm		
Muscle	793	792
Bone[2] (radius and ulna)	211	186
Hand		
Muscle	106	136
Bone[2] (articulated hand)	140	114

[1] The animal was skinned prior to dissection, so the skin component is missing for these segments.
[2] All bones were weighed at time of dissection and before cleaning.

Table IV. Bone lengths: male *Pan paniscus* Amos (mm)

	Right (normal)	Left (abnormal)
Humerus	266	264
Radius	255	254
Ulna	266	266
Metacarpal I	40	39
Metacarpal II	84	83
Metacarpal III[a]	83	81[b]
Metacarpal IV	77	62[b]
Metacarpal V	71	59[b]
Digit I proximal phalanx	32	29
Digit II phalanges		
Proximal	46	44
Middle	30	29
Distal	16	16
Digit III phalanges		
Proximal	56	54
Middle	39	39
Distal	19	21
Digit IV phalanges		
Proximal	52	48
Middle	35	34
Distal	19	19
Digit V phalanges		
Proximal	42	38
Middle	30	23
Distal	15	14

[a] Mean length for metacarpal III in 5 male *Pan paniscus* = 83 [Susman, 1979].
[b] Estimates, because fused with three joint surfaces (fig. 3).

bones not immobilized during healing. The proximal phalanx of digit III was strongly curved and the radiograph revealed a bony outgrowth (exostosis) on its dorsal side. This digit probably served during life as the primary weight-bearing surface during quadrupedal knuckle-walking, which might account for the exostosis. The middle phalanx was curved and lengthened compared to the normal hand, and the distal phalanx was also lengthened. The entire digit was long and was extremely flexed during life (fig. 1). It could not be extended even after dissection. Digits IV and V were incomplete, with only partial proximal phalanges present (fig. 1). During dissection, prominent fat pads were found under the skin on the ends of these two partial phalanges.

Bone Density. Bone mineral index values for radius and ulna of the affected left side were lower than for the corresponding bones on the unaffected right side [Morbeck and Sumner, work in progress]. Bone mineral index of the right radius was 2.09 compared to 1.86 on the left; right ulna was 1.85 compared to 1.77 on the left. This finding matches the lighter bone weights of the radius and ulna on the affected left side.

Fig. 2. Radiograph of abnormal left hand of adult female pygmy chimpanzee (Lokalema). Left arrow indicates dorsal exostosis on digit III; right arrow indicates the pseudoarthrosis on digit II. Metacarpals IV and V with attenuated proximal phalanges are shown on the right.

Amos, Adult Male, 11 Years of Age

Prior to dissection, the hand appeared relatively normal. Digits IV and V appeared somewhat close together, and set at an angle on a different plane from the second and third digits. The extent of the abnormality was not evident until all the muscle tissue was removed. Although the total muscle and bone weights were similar in the two hands (right = 246 g vs. left = 249 g), tissue composition differed. The left abnormal hand had more muscle, but less bone than the normal side. The upper arm and forearm segments in both sides were similar, with little difference in tissue composition (table III). The main bone deformity centered on the fusion of metacarpals II, IV and V into one bone with three joint surfaces. Consequently, digits IV and V were angled and more flexed (fig. 3).

Bone Lengths (table IV). The humerus, radius and ulna did not differ in length between right and left sides, nor did the phalanges of digits II and III. The metacarpals were longer to varying degrees in the normal right side. For example, metacarpals IV and V differed by 22 and 18.6%, respectively.

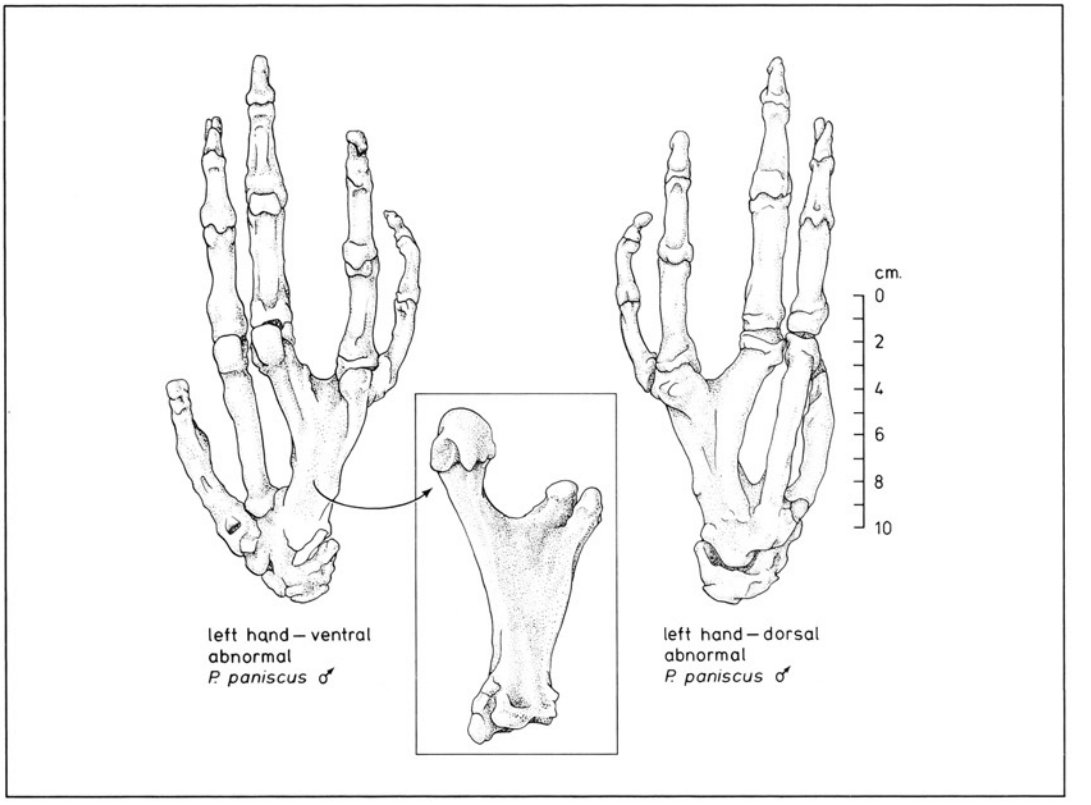

Fig. 3. Abnormal hand of adult male pygmy chimpanzee (Amos; FMNH 60770). Drawn from slide of dissected, articulated hand photographed prior to cleaning. Fused metacarpals drawn from disarticulated and cleaned hand.

Other notable differences showed up in the two proximal phalanges of digit I (11%), and in the proximal and middle phalanges of digit V, which showed 11 and 27% difference, respectively. Amos had other abnormalities. There were a total of four additional premolars, one in each quadrant of the upper and lower jaws. His right foot was reported to be abnormal in records kept on him during his life, but the foot had been removed from the cadaver and was not available for study.

Adult Female (MCZ No. 38019)

In figure 4 the hand is illustrated (from a photograph) as it appears in the Museum of Comparative Zoology, Harvard University collection. The main abnormality was the presence of only one unusually shaped phalanx on digit II and what appears as a large metacarpal-phalangeal joint. The terminal phalanx of the thumb was missing, as was also the case for Amos. I believe that this loss occurred post mortem and is therefore not an abnormality.

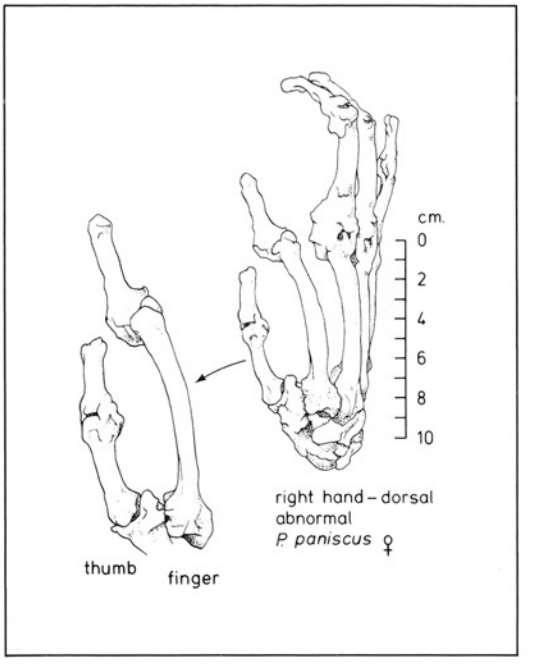

Fig. 4. Abnormal hand of adult female pygmy chimpanzee (MCZ 38019). Drawn from photograph.

Discussion

Hand malformations were studied in 2 pygmy chimpanzees. The normal and abnormal hands were found to be asymmetrical in linear bone dimensions and in tissues mass proportions, as determined from dissection, radiographs and bone mineral analysis. In both specimens, the abnormal hand had greater muscle mass and lighter bone.

In one individual, the female Lokalema, the forearm also showed asymmetry in the mass of muscle, skin and bone. The lower mineral content of the affected radius and ulna may be related to the lesser development of forearm muscles. The more limited functioning of the abnormal hand probably contributed to the differential development of its muscles. In contrast, in the male Amos, the forearm muscles and bone did not show any asymmetry.

Traumatic changes in Lokalema's hand are superimposed on the developmental abnormality, as revealed by radiographs. A pseudarthrosis is evident in the shaft of the proximal phalanx on digit II, probably a result of incomplete healing of a broken bone. The radiograph also reveals an exostosis on the dorsal middle phalanx of digit III. The exostosis as well as the longer and more robust nature of this digit suggest a reliance on this digit for weight-bearing during locomotion.

Other Comparisons

Hand abnormalities have been found in other nonhuman and human primate species. In free-ranging chimpanzees *(Pan troglodytes)* Goodall [1983] reports hands affected by injury and disease. Of 81 pygmy chimpanzees *(Pan paniscus)* contacted in the Lomako Forest, 17 deformities were evident in the hands or feet [N. Thompson-Handler, pers. commun.]. Like the report from Wamba [Kano, 1984], the infants and juveniles of the Lomako population did not exhibit abnormal limbs.

Studies on populations of free-ranging Japanese macaques *(Macaca fuscata)* show a high rate of congenital malformations of limbs [Itani et al., 1963; Furuya, 1966]. Iwamoto [1967] documented the congenital malformations in captured individuals using palpation, X-rays and anatomical dissections. Abnormalities were more frequent in the hand than in the foot and were not found in the foot alone. The reason for the relatively frequent occurrence of such malformations, whether genetic or developmental, is unclear.

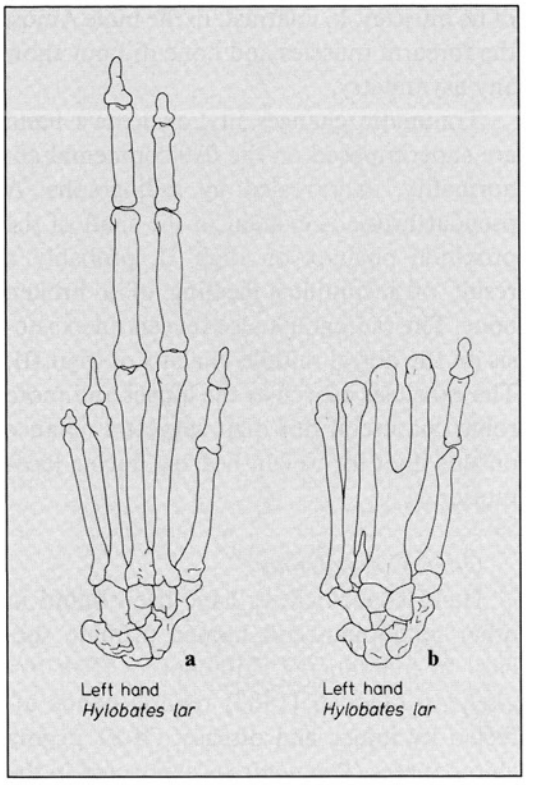

Fig. 5. a, b Hand abnormalities in 2 gibbons, *Hylobates lar* [after Schultz, 1944].

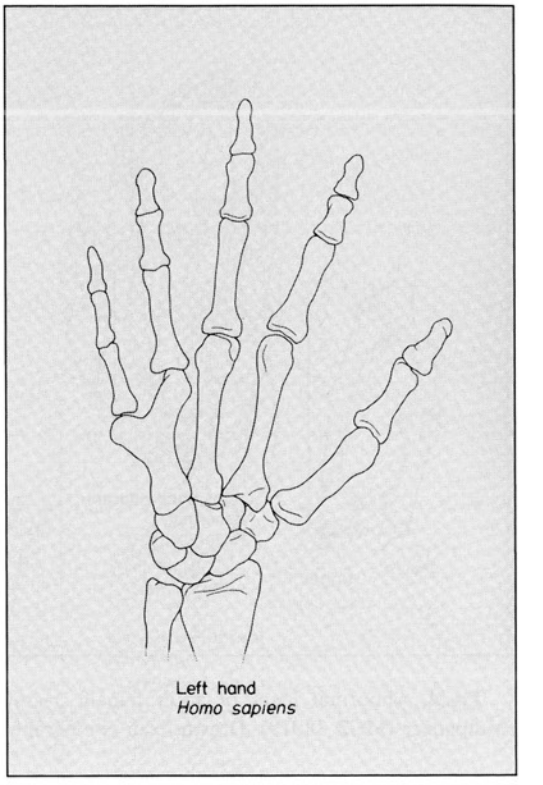

Fig. 6. Fused or absent metacarpal in human hand [modified from Buckwalter et al., 1981].

Anatomical study of split hand and foot anomalies in three rhesus macaques, *Macaca mulatta,* suggests that two different developmental patterns and possibly two different genotypes may underlie the anatomical differences observed [Morris and Kerr, 1971]. A literature survey pertinent to nonhuman primate limb abnormalities prompted Morris [1971, p. 335] to suggest that 'in some primate populations the incidence of limb abnormalities is significantly higher than in human populations'.

Abnormalities in primate skeletons approximating those reported here have been extensively documented by Schultz [1944, 1956, 1958, 1972]. A gibbon (fig. 5a) with missing middle and distal phalanges of digits IV and V resembled the female pygmy chimp shown in figure 1. Schultz [1972] also found a mandrill with similarly missing phalanges in digits IV and V. Another gibbon (fig. 5b) had partial fusion of metacarpals II and III.

Congenital absence of digits or parts of digits occurs 'normally' among other primates. For example, among orangutans, the hallucial nail and terminal phalanx are congenitally absent in possibly 60% of orang-

utans [Schultz, 1941; Tuttle and Rogers, 1966]. This frequency may be selected for, or at least not selected against, in orangutans. It is unusual for congenital reduction or absence of digits to occur more frequently in the feet than in the hands [Tuttle and Rogers, 1966; Schultz, 1941].

Congenital malformations in human hands are many and variable, and are often associated with syndromes. One unusual case of the absence of the fifth metacarpal, represented by the apparent fusion of metacarpals IV and V, is shown in figure 6 after Buckwalter et al. [1981]. Fusion of three metacarpals, as in Amos, in an otherwise normal hand is probably even more uncommon [see for example Poznanski, 1974; Kelikian, 1974, and Dwight, 1908, for examples of missing phalanges and fused metacarpals].

It is difficult to assess the frequency of hand abnormalities arising congenitally rather than from trauma among free-ranging pygmy chimpanzee populations. Samples are small, and external appearance and function can be misleading. Dissection and radiographs are needed to establish the origin with some certainty. If congenital abnormalities do occur, then factors which contribute to their expression, whether genetic or developmental, remain to be determined.

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