Volume : 3 | Issue : 2 | February 2014 • ISSN No 2277 - 8179

Research Paper

In Relation with Evolutionary Development- the Study of Differences Between the Chimpanzee Thumb and the Human Thumb

Medical Science

KEYWORDS : Chimpanzee, Human thumb, Evolution, precision grip, power grip, hominid lineage

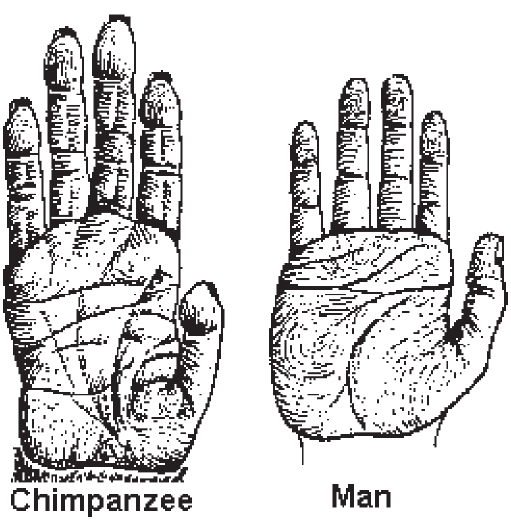
Dr. Deepak Howale	Professor & Head Department of Anatomy, GMERS Medical College, Valsad (Gujarat)
Dr Anil Bathija	Associate Professor Department of Anatomy, GMERS Medical College,Gotri,Vadodara (Gujarat)
Dr Sudarshan Gupta	Assistant Professor Department of Anatomy, GMERS Medical College,Valsad (Gujarat)
Dr D P Pandit	Professor & Head Department of Physiology, GMERS Medical College, Valsad (Gujarat)

ABSTRACT

It is often said that the defining trait which separates man from the animals is an opposable thumb. Without the opposable thumb, human beings might never have enjoy the highly civilized, sophisticated, and technological lifestyles. Opposable thumbs are required for efficient gripping of objects as well as handling fine objects, the skill of refining objects It is interesting to note that a there are species which are similar to humans in brain capacity but lacks in opposable thumb. The chimpanzees due to the lack of an opposable thumb have extremely creating anything more complex than what they already find in their natural surroundings.The emergence of painting, sculpture, and music would have been unthinkable, man require thumbs to hold paint brushes, chisels, and musical instruments.Thus, the opposable thumb to man's uniqueness and development. It has been proposed that the hominid lineage (hominid or Hominidae- which includes humans and the great apes like bonobos, chimpanzees, gorillas, and orangutans&lineage means -Derivation or Direct descent from a particular ancestor) began when a group of chimpanzee-like apes began to throw rocks and clubbing behaviours, This assertion leads to the prediction that the human hand should be adapted for throwing and clubbing. It is shown that the two fundamental human handgrips, first identified by J. R. Napier, and named them as the 'precision grip' and 'power grip', represent a throwing grip and a clubbing grip, and provides an evolutionary explanation for the two unique grips, and the extensive anatomical remodelling of the hand that made them possible. These results are supported by palaeoanthropological evidence.1

INTRODUCTION

The typical primate hand is characterized by a small thumb in combination with long, curved fingers . In contrast, the human hand has a much larger, more muscular, mobile, and fully opposable thumb combined with fingers that have shortened and straightened [2](Fig. 1). The anatomical reconstruction of the hand during human evolution was linked with *tool behaviour*. Which gives evidence that an early hominid (hominin) behaviour was bipedal gait, which would have 'freed the hands' for greater use of tools



(Fig. 1)Chimpanzee hand, the hand of the hominid ancestor (left), and the human hand[2].

Evolution

The chimpanzee hand

The chimpanzee hand is a model for the hand of the hominid ancestor. The most ancient hominid fossils closely resemble chimpanzees, who are genetically our nearest relatives [3,4] *Pan* and human lineages diverged 5–7 million years ago about the time the first hominid specimens appear in the fossil record. The fingers, metacarpal and carpal bones of the chimpanzee hand are elongated, but the thumb is small, weak and relatively immobile [5] (Figs 1 and 2). The third and fourth metacarpals, which absorb the highest compression during knuckle-walking, are especially strong& vigorous.[6] Both proximal and middle phalanges are curved toward the palm to withstand stress from gripping limbs during is the locomotion in trees (arboreal locomotionThe finger tips are coneshaped ,the transverse arrangement of the metacarpo-phalangeal articulations, there is a transverse skin crease across the palm[7.] (Fig. 1). Thumb phalanges and metacarpals are slender and short (Fig. 2) and the intrinsic muscles of the thumb, the thenar region of the palm, are small and weak.

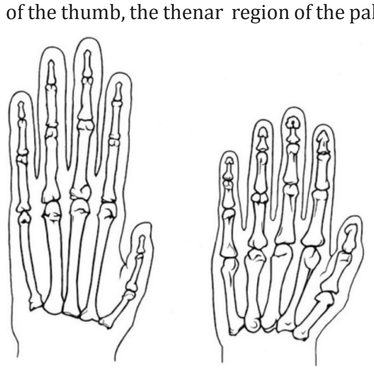


Fig. 2

Bones of the chimpanzee (left) and human hands[2].

The grips of the chimpanzee differ profoundly from those of humans[7.] For suspension from horizontal supports, chimpanzees use a 'hook grip' of the four flexed fingers [8] With vertical supports, a diagonal hook grip is used (The thumb may touch the support, but does not squeeze it against the palm. Chimpanzees use this grip when flailing with sticks, but when the arm swings forward the hand tends to lose its grip, possibly due to weakness of the thumb and its inability to overlap the index finger[8.] Because the thumb is weak and short, its distal phalanx is relatively immobile and its distal pad cannot be opposed to those of the fingers, it cannot generate a firm pinch or squeeze[9,10,11,]

The human hand

The human thumb is longer as compare with chimpanzee, the palm and fingers are shorter, and the fingers have lost their curvature[12] The distal phalanges have gained broad, palmar, fibrofatty pads that distribute pressure during forceful grasping and accommodates the pads to uneven surfaces [13 14.] Apart from thickening of the fifth metacarpal and enlargement of its base, the balance of strength and robusticity has shifted radially, to the thumb, second and third fingers The thumb metacarpal articulates with the carpals in a saddle joint which in combination with the metacarpophalangeal joint allows its distal pad to be placed against those of the other fingers, providing full opposability [15] The intrinsic thumb muscles are larger[16], and three new muscles add strength and control to thumb movements. The flexor pollicis longus muscle, is the most powerful thumb muscle in humans. (Which is absent in chimpanzees) It flexes the distal phalanx of the thumb and maintains the orientation of its pad toward the fingers against pressure. The deep head of the flexor pollicis brevis and the first palmar interosseous muscle[17] . The palm shows several derived features. Because the fourth and fifth metacarpals are progressively shorter than the third, there is an obliquity to the hand when it is flexed. This produces flexure creases that run obliquely, from the lower ulnar side of the palm to the upper radial side [18]The thenar and hypothenar eminences are enlarged by fat pads which overlie the muscles. Contraction of the palmaris brevis muscle stiffens the hypothenar pad and increased the ability of the centre of the palm to withstand stress imposed along the second and third fingers [19]The metacarpals and bases of the proximal phalanges of these fingers are robust. A palmar fat pad in the third metacarpal region protects the deep branch of the ulnar nerve. Stability of the third metacarpal base is enhanced by a styloid process on its dorsal radial aspect. When the finger is extended, the styloid process locks the carpal and metacarpal bones together, preventing hyperextension. A pisiometacarpal ligament from the pisiform bone to the third metacarpal base also prevents hyperextension.

DISCUSSION

Humans have an opposable thumb, meaning that they are able to simultaneously flex, abduct and medially rotate the thumb (pollex) so as to bring its tip into opposition with the tips of any of the other digits. This ability is facilitated by a sellar (saddle-shaped) joint between the trapezium (the carpal bone that supports the thumb) and the first metacarpal, which allows an approximately 45° range of rotation of the thumb about its own long axis. Humans share opposability with most other catarrhines (old world monkeys and apes). However, humans differ from other primates in having a relatively longer and more distally placed thumb (Relative Thumb Length) and in having larger thumb muscles (the thumb muscles constitute about 39% of the mass of the intrinsic hand muscles in humans, as compared to only 24% in chimpanzees). These differences, especially with relative thumb length, make it difficult for non-human primates to do tip-to-tip precision grips when manipulating small objects (such that small objects must generally be pressed by the thumb against the lateral side of the index finger). The greater mobility of the human thumb, and enhanced ability to manipulate small objects with thumb tip-to-finger tip

Another attribute of the human hand concerns finger rotation. When the fingers are flexed, they rotate towards the central axis so that the fingertips can meet the tip of the thumb. The metacarpohamate articulation permits supination of the fourth and fifth metacarpals, whereas the heads of the second and third metacarpals allow pronation of the proximal phalanges. Rotation is more pronounced for the two outermost fingers [12 10,20,]

The two unique human hand grips

Napier illustrated the two grips, grasping a ball and a cylindrical rod. During its evolution, the human hand gained two unique grips, first identified by Napier. He called them the precision grip and the power grip and depicted them by the grip of a sphere and a cylinder [1,7,15,21,22,23,] The unique nature of the human thumb and the importance of its role in the differentiation of humans from our closest relatives. A primitive autonomization of the first carpometacarpal joint (CMC) may have occurred in dinosaurs. A real differentiation appeared perhaps 70 mya in early primates, while the shape of the human thumb CMC finally appears about 5 mya. The result of this evolutionary process is a human CMC joint positioned at 80° of pronation, 40^0 of abduction, and 50° of flexion in relation to an axis passing through the second and third CMC joints. [24] Opposable thumbs are shared by many primates, including most simians, and some prosimians. The climbing and suspensory behaviour in orthograde apes, such as chimpanzees, has resulted in elongated hands while the thumb has remained short. As a result, these primates are unable to perform the pad-to-pad grip associated with opposability. However, in pronograde monkeys such as baboons, an adaptation to a terrestrial lifestyle has led to reduced digit length and thus hand proportions similar to those of humans. Consequently, these primates have dexterous hands and are able to grasp objects using a pad-to-pad grip[25]

A review of thumb morphology in both locomotor and manipulative behavior, built upon a common framework that first appeared in the paired inpectoral fins of early bony fishes approximately 400 million years ago[26]

The pentadactyl pattern of the mammalian hand, with carpals, metacarpals, and phalanges, including a ray corresponding to the human thumb,was already established more than 350 milion years ago Fossil remains of later labyrinthodont amphibians and mammal-like reptiles document the history of features that distinguish the mammalian hand from the fin of the ancestral lobefin fish[6]. Among land mammals, the|thumb has been retained primarily in marsupial(kangaroo,kolabearwombbats) and placental species that move about in the.small-branches of the forest[27]

The source of the human's ability to position the palmar tip of the thumb in opposition to the palmar aspect of the fingers may be found in this primitive mammalian adaptation to grasping small branches[28]. The branches are too slender and flexible to be secured by the parallel application of clawed digits. The friction surfaces on the thumb, fingers, and palm firmly enclose the branch and provide support during feeding and as the animal moves by a grasping-climbing mode of locomotion along and between branches.

Opposition of the thumb to the fingers is facilitated by a saddle joint between the trapezium and first metacarpal, which has been found by Lewis[6]

Humans share with all primates the intrinsic muscles that produce movements at the first carpometacarpal and metacarpophalangeal joints. Homologies among elements of this muscle group are reviewed by Lewis. Humans also share with several species a long thumb relative to total hand length (Table 1; Fig. 3). The baboon has the highest index It walks on the palmar surface of the phalanges, with the metacarpals hyperextended and held in line with the forearm.because its fingers have become short relative to the metacarpals as part of its adaptation to terrestrial digitigrade locomotion.

Table No 1; Average Thumb/Hand Length Index

Genus	Thumb/Finger Index
Homo	67
Apes	
Pan(Chimpanzee)	47
Gorilla	54
Pongo(Orangutan)	43
Hylobates(Gibbon)	52
Old World monkeys	
Papio(baboon)	68
Macaca	56
Presbytis(Langur)	40
Colobus	36

Saguinus(Squirrel monkey)	60
Alouatta(Howler monkey)	58
Prosimians	
Loris	63
Lemur	52
Galago	61
Tarsius	54

The tendon of the flexor pollicis longus muscle in humans arises from fibers that are separate along their full length from the flexor digitorum profundus muscle to the four fingers.[6] In other primate species the tendon to the thumb generally originates from muscle fibers that are continuous with those that give rise to finger tendons[29]. The separation of the flexor pollicis longus from the flexor digitorum profundus,, muscle in humans permits the fingers to flex independently of the thumb. A similar separation of the deep flexor mass occurs occasionally in the gibbon [29] An ape whose thumb is held adducted against the side of the palm or folded against the dorsum of the hand when the fingers are flexed around branches during climbing and brachiation.[30]

The tendon to the thumb is frequently absent in the three larger apes more closely related to humans (the orangutan, gorilla, and chimpanzee), whose fingers are so long that the thumb generally functions in manipulative behavior with the side of the index finger rather than with the tips of the fingers. [29]

Humans have a broader pad on the palmar aspect of the distal pollical phalanx than in other primates. Comparative dissections have shown that the human pad is distinctive not only in its breadth but also in its division into two compartments, with the proximal compartment being more mobile and deformable than the distal[31,32,]

The division is reflected on the bone by two features:-

(1) ungual spines, to which radial and ulnar tuberospinous ligaments attach that provide support to the mobile proximal ungual pulp, and
(2) a broad ungual tuft, which provides attachment to radiating fibrous bands of fascia that limit the mobility of the distal compartment. The compartmentalization appears to provide flexibility in optimizing friction and stabilizing objects held between various combinations of the distal and proximal pads of the thumb and index finger[32]

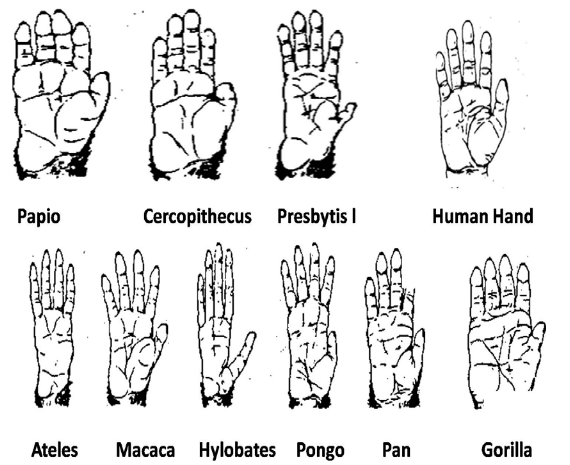


Figure 3. Showing hands &thumbs of other **Primate and human hands.**
(Figure taken from Schultz AH: The Life of Primates. London, Weidenfeld and Nicolson, 1969)

Humans are also distinctive in the relative mass of the intrinsic thumb musculature. This constitutes 39% of the total hand intrinsic musculature weight, compared with 33% in gibbons and 24% in the chimpanzee and orangutan[33]Forces generated by contraction of the extrinsic and intrinsic muscles to the thumb are sustained and transmitted by joint surfaces that are proportionately larger than the chimpanzee. The carpometacarpal joint surface is broader on the ulnar aspect than to the radial aspect than in the chimpanzee, and the joints between the trapezium and both the trapezoid and scaphoid are larger than the joint between the trapezoid and scaphoid[11]. The saddle surface of the trapezium in humans appears to be flatter in a dorsopalmar direction than the chimpanzee.The proportionately long thumb, short fingers, and well-developed flexor pollicis longus muscle in humans permit effective exploitation of the broad palmar pads on the thumb. The finger tips can meet the pressure of the thumb tip in a moderately flexed position that permits their extrinsic flexor musculature to exert considerable force on an object against the thumb tip. The broad compartmentalized distal palmar pad of the human thumb, together with the relatively large flexor pollicis longus muscle and intrinsic muscles, contribute to force of these grips in humans. The mobile part of the pad also permits the thumb to move skillfully objects with the comparable portions of the fingers, providing more control of the objects than in the nonhuman primates.

SUMMARY & CONCLUSION

The bones and joints of the human thumb are a mosaic of primitive and unique features, reflecting stages in the evolution The trapeziometacarpal saddle joint ,the broad distal phalanx with its specialized palmar pad is unique to humans.The human thumb shows a firm grip and tolerance of large stresses. Hominidae, had short thumbs relative to the length of the fingers, which can not tolerate the large stresses associated with modern human manipulative behavior. Late hominids had very flat trapeziometacarpal joints and large distal phalanges, indicating a capacity for opposition of the thumb to all four fingertips and for tolerance of large stresses.

Table No 2-Difference observed in this study is as follows-

Hand	Human	Chimpanzee
Fingers	Straight	Curved
Thumbs Distal phalynx of thumb metacarpals	Much longer& strong Mobile Stability of the third metacarpal base is enhanced by a styloid process on its dorsolateral aspect. When the finger is extended, the styloid process locks the carpal and metacarpal bones together, preventing hyperextension.	Short&weak Immobile The third and fourth metacarpals, which absorb the highest compression during knuckle-walking, are especially strong& vigorous.
Movement The thumb muscles	Opposable constitute about 39% of the mass of the intrinsic hand muscles Thumb squeeze(firm pinch) against the palm	Not opposable Only 24% mass of the intrinsic hand muscles Do not squeeze against the palm

Grips Precision grip, Power grip, Finer grip,	Precision grip-Able to hold the object in between forefingers &thumb, Power grip-Able to wrap Fingers & thumbs around object Power grip, Finer grip possible	Not able to do precision grip, Power grip & Finer grip not possible But hook grip is present when flailing with sticks
Thenar muscles	Strong	Weak
Saddle joint	present	Absent
3 new additional muscles flexor pollicis longus The deep head of the flexor pollicis brevis and first palmar interosseous muscle	present	All 3 muscles are Absent

REFERENCE

1 J. R. Napier, "The prehensile movements of the human hand,"J. BoneJoint Surg., vol. 38B, pp. 902–913, 1956 | | 2 Mary W. Marzke And R. F. Marzke :J Anat. 2000 July; 197(Pt 1): 121–140. oi: 10.1046,j.1469-7580.2000.19710121.x | | 3 Sibley CG: DNA-DNA hybridisation in the study of primate evolution. In: Jones S, Martin R, Pilbeam D, editors. The Cambridge Encyclopedia of Human Evolution. Cambridge: Cambridge University Press; 1992. pp. 313–315 | | 4 Ruvolo, M. 1997. Molecular phylogeny of the Hominoids: Inferences from multiple independent DNA sequence data sets. Molecular Biology and Evolution 14:248-265 | | 5 Midlo C. Form of hand and foot in primates. Am. J. Phys. Anthropol. 1934;19:337–389 | | 6 Lewis OJ: Functional Morphology of the Evolving Hand and Foot. Oxford, Clarendon Press, 1989 | | 7 Napier JR. Studies of the hands of living primates. Proc. Zool. Soc. London. 1960;134:647–657 | | 8 Marzke MW, Wullstein KL, Viegas SF. Evolution of the power (squeeze) grip and its morphological correlates in hominids. Am. J. Phys. Anthropol. 1992;89:283–298. | | 9 Marzke MW. Evolution of the hand and bipedality. In: Lock A, Peters A, editors. Handbook of Human Symbolic Evolution. Oxford: Oxford University Press; 1992a. pp. 126–154. | | 10 Marzke MW. Precision grips, hand morphology and tools. Am. J. Phys. Anthropol. 1997;102:91–110. | | 11 Marzke MW, Wullstein KL, Viegas SF: The power ("squeeze") grip and its morphological correlates in hominids. Am J Phys Anthropol, in press | | 12 Susman RL. Comparative and functional morphology of hominoid fingers. Am. J. Phys. Anthropol. 1979;50:215–236. | | 13 Napier JR. Evolution of the human hand. Proc. Royal. Inst. Great Britain. 1965;40:544–557 | | 14 Marzke MW, Shackley MS. Hominid hand use in the Pliocene and Pleistocene: evidence from experimental archaeology and comparative morphology. J..Human Evol. 1986;15:439–460 | | 15 Napier JR. The form and function of the carpo-metacarpal joint of the thumb. J. Anat. 1955;89:362–369 | | 16 Marzke MW. Evolutionary development of the human thumb. In: Manske PR, editor. Hand Clinics and Thumb Reconstructions. Vol. 8. Philadelphia: W.B. Saunders; 1992b. pp. 1–8. | | 17 Susman RL. Fossil evidence for early hominid tool use. Science. 1994;265:1570–1573 | | 18 Napier JR. Hands. Princeton, New Jersey: Princeton University Press; 1993 | | 19 Mary W. Marzke And R. F. Marzke J Anat. 2000 July; 197(Pt 1): 121–140. doi: 10.1046 j.1469-7580.2000.19710121.x | | 20 Marzke MW. Joint functions and grips of the Australopithecus afarensis hand, with special reference to the region of the capitate. J. Human Evol. 1983;12:197–211. | | 21 Napier JR. The form and function of the carpo-metacarpal joint of the thumb. J. Anat. 1955;89:362–369 | | 22 Napier JR. Hands and handles. New Scientist. 1961;9:797–799. | | 23 Napier JR. Fossil hand bones from Olduvai Gorge. Nature. 1962;196:409–411. | | 24 Young, Richard W. (January 2003). "Evolution of the human hand: the role of throwing and clubbing". Journal of Anatomy 202 (1): 165–174. doi:10.1046/j.1469-7580.2003.00144.x. | | 25 Moyà-Solà, Salvador; Köhler, Meike; Rook, Lorenzo (January 5, 1999). "Evidence of hominid-like precision grip capability in the hand of the Miocene ape Oreopithecus". PNAS 96 (1): 313–317. Bibcode:1999PNAS...96..313M. doi:10.1073/pnas.96.1.313. PMC 15136. PMID 9874815 | | 26 Cartmill M, Hylander WL, Shafland J: Human Struc¬ture. Cambridge, Harvard University Press, 1987 | | 27 Jenkins FA: Tree shrew locomotion and the origins of primate arborealism. In Jenkins FA (ed): Primate Locomotion. New York, Academic Press, 1974, p 85 | | 28 Cartmill M: Rethinking primate origins. Science 184:436, 1974 | | 29 Marzke MW: Origin of the human hand. Am J Phys Anthropol 34:61, 1971 | | 30 Van Horn R: Structural adaptations to climbing in ' the gibbon hand. Am Anthropol 74:326, 1972 | | 31 Shrewsbury MM, Johnson RK: Form, function, and evolution of the distal phalanx. J Hand Surg 8:475, 1983 | | 32 Shrewsbury MM, Sonek A: Precision holding in humans, non-human primates, and Plio-Pleistocene hominids. Hum Evol 1:233, 1986 | | 33 Tuttle RH: Quantitative and functional studies of the hands of the Anthropoidea. J Morphol 128:309, 1969 |