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Review Articles

Esthetic Anatomy of Hands in Medicine and Art

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The evolutionary process of the development of hands and fingers has been one of the most distinctive properties of the human species. While no hand, or even fingers of the same hand, is alike, there is no standard size and proportion due to gender, race, geography, repetitive occupations, and genetics. However, generally accepted hand proportions can be used in clothing design, ergonomic design of hand tools, implants used in hand surgery, biomechanical prosthesis development, and forensic research. Some hand characteristics may be similar in some specific populations, especially people with genetic disorders. Additionally, hand anthropometry may change, especially in musicians and sportspeople, because of constantly repetitive movements. Furthermore, hand anatomy has also been a source of inspiration for many artists. They emphasized hands in their art pieces using different methods according to the scope of art movements with which they were impressed. This review aimed to assess the anatomic, medical, and artistic implications of hand proportions.

Key words: artistic anatomy, hand, medicine in art, proportion, regional anatomy, science in art

Introduction

The evolutionary process of the development of hands and fingers has been one of the most distinctive properties of the human species [8]. The appearance of the human hand differs individually. While no hand, or even fingers of the same hand, is alike, there is no standard size and proportion due to gender, race, geography, repetitive occupations, and genetics. However, generally accepted hand proportions can be used in clothing design, ergonomic design of hand tools, implants used in hand surgery, biomechanical prosthesis development, and forensic research [19; 41]. Some hand characteristics may be similar in some specific populations. For instance, genetic diseases such as Marfan syndrome, Fragile X syndrome, Down syndrome, and achondroplasia also have typical hand appearances [31; 48; 55; 59; 62; 69; 76; 79].

Hand anatomy has also been a source of inspiration for many artists. Furthermore, talented artists and leading scientists collaborated to create realistic images of the dissected anatomical parts. As a result of this collaboration, anatomical paintings and sculptures with high artistic value have emerged. The concept of "artistic anatomy" was born with the fusion of science and art.

This review aimed to evaluate the anatomic, medical, and artistic implications of hand proportions.

Hand Types

Hands hitherto have been classified differently by many authors [3; 45; 84]. The best-known of these classifications is constitutional typology, defined by Kretschmer. Accordingly, body types were defined as asthenic, athletic, and pyknic, and then the measurements of the hands in males and females of these body types were specified [44]. Later on, Sheldon defined somatotypes as endomorphy, mesomorphy, and ectomorphy according to morphological structures [77]. Sheldon's body type sorting is today's most accepted and frequently used classification in academic studies. Accordingly, ectomorph refers to long, thin fingers and weak hands, endomorph refers to short and thick fingers and broad and plump hands, and mesomorph refers to broad and muscular hand types [40] (**Fig.1**). Other subtypes are the combinations of these three somatotypes.

Ectomorphic Hand **Mesomorphic Hand** **Endomorphic Hand**

Fig. 1. Hand types according to Sheldon's description. **Left:** ectomorphic hand: a weak hand with long and thin fingers; **Middle:** mesomorphic hand: a muscular hand; **Right:** endomorphic hand: broad and plump hand with short and thick fingers.

In addition to the previously determined classifications for hands, there are some basic rules and approximate ratios for hand proportions:

The hand palm starts from the distal skin fold of the wrist and ends at the apparent base of the fingers. The webs between fingers form the apparent base of the fingers. However, the actual base is formed by the metacarpophalangeal joints. It is difficult to evaluate the hand bones with an external view due to the individual differences in the surrounding soft tissue. Still, hand bones can be better visualized using various radiological imaging methods.

Embryogenesis

Hand development is a complex process orchestrated by a plethora of molecular signals within the upper limb. With both stimulatory and inhibitory effects, these signals regulate cell proliferation and apoptosis, shaping the skeletal structures and spaces of the hand. Understanding the intricacies of hand development is essential for comprehending congenital malformations affecting the hand.

The upper extremity's genesis begins with a lateral bulge in the C5-8 and T1 myotomes around the 27th intrauterine day [11]. This bulge eventually forms a bud comprised of mesenchymal cells originating from both the somitic and lateral plate mesoderm, covered by ectoderm. While the lateral plate mesoderm contributes to cartilage and bone structures, the somitic mesoderm gives rise to limb musculature. By the fourth week of development, arm buds become discernible and expand, vascular structures emerge, and the hand plates take on a paddle-like formation [80]. Around day 36, nerve growth into the limb structure starts, and the digits begin to form as chondrogenic condensations along the distal hand paddle [23].

The first joint (shoulder) appears on the 36th day, and the last appears on the 47th day (in hand) [4]. By around 47 days, digits form as digital rays separated by flattened interdigital tissue, which subsequently undergoes apoptosis, allowing for digit formation. Towards the end of the eighth week (52nd day), separate fingers form with apoptosis of the mesenchymal tissue between the fingers [23; 82]. Within the seven weeks of development, carpal chondrification and muscle group formation commence. The size of the limb bud is influenced by factors such as the number of progenitors, proliferation rate, and cell death, with abnormalities in these factors leading to modifications in digit number and pattern. Chondrification progresses from proximal to distal, and phalanges chondrify around the 50th day [4]. Ossification of cartilaginous elements begins approximately at the sixth week and extends distally to the wrist and hand by the eighth week.

Postnatal growth significantly contributes to upper extremity development. Myelinization is completed around the age of two years, alongside the continuation of ossification of the carpus and epiphyses of the hand.

Key regulatory molecules such as fibroblast growth factor (FGF) 10 and T-box transcription factor-5 play pivotal roles in the bulging and budding on the 27th day [11]. Limb development is guided by specialized signaling centers, including the apical ectodermal ridge (AER), the zone of polarizing activity (ZPA), and the non-ridge ectoderm. These signaling centers secrete molecules regulating coordinated limb growth. The AER guides limb outgrowth along proximodistal through FGFs. A disruption in the FGF pathway leads to transverse limb defects. The ZPA directs the anteroposterior limb growth via Sonic Hedgehog (Shh). An impairment in Shh secretions leads to mirror image duplication on the limb and phalanges. The non-ridge ectoderm controls the limb growth in the dorsoventral axis through the balanced work of the Engrailed-1 transcription factor. The Engrailed-1 expression directs the ventral patterning by restricting the dorsalization by inhibiting Wnt7a [23; 50]. A disturbance in dorsoventral maturation causes dorsalization defects such as palmar nail syndrome [71].

The chondrogenesis of the digit ray is mainly affected by the Transforming growth factor beta (TGF-β), SRY-related HMG-box (SOX) genes (specifically SOX9), FGFs, and bone morphogenic proteins (BMP) (specifically BMP-2) [2; 43]. The joint formation is dominated by the inhibition of chondrogenesis and apoptosis through the action of the TGF-β superfamily (mainly cartilage-derived morphogenetic protein-1) and the Wnt family (Wnt-4 and Wnt-14) [33; 49; 51]. The formation of separate digit process through programmed cell death is affected by the transcription factors such as muscle segment homeobox (Msx) (Msx-1 and Msx-2) and homeobox (Hox-7), and proteins including BMP-2, BMP-4, and BMP-7 [11]. The interruption of apoptosis of interdigital mesenchymal tissue at any stage of the developmental period results in deformations in interdigital web spaces. This way, congenital web space anomalies such as webbed hands-feet or syndactyly occur [82]. The Hox-D group has a significant role in anteroposterior limb growth, in which the mutations in the Hox-D family can produce various types of synpolydactyly [64]. A mutation in Shh can cause radial polydactyly and thumb anomalies [1].

Hands and Fingers

Interphalangeal and metacarpophalangeal joints are not aligned in a straight line. When three lines passing through the proximal interphalangeal joints, distal interphalangeal joints, and metacarpophalangeal joints are drawn, these lines form a parallel arc. In the resting position, the fingers slightly bend towards the third finger. In the anatomical position, the angle between the first and the fifth metacarpal bones is approximately 90 degrees [61].

Each finger is different in length. The longest finger is the middle finger. The index finger can guide some of the basic measurements of hands. For example, the palm width, the sum of the lengths of the thumb and the first metacarpal bone, and the distance from the second metacarpophalangeal joint to the end of the palm are basically equal to the length of the index finger [25]. The distance corresponding to the longest line of the palm (from the wrist line to the third metacarpophalangeal joint) is equal to the length of the middle finger [65]. These esthetic anatomy rules are the measurements that artists often use in their hand drawings.

Digit proportions show regional, racial, and gender differences. It has also been demonstrated to play a role in functional dexterity and thermoregulation. Thicker index and middle fingers are associated with low dexterity [68; 74]. Furthermore, a shorter and broader first metacarpal bone has been observed in populations living in cold climates [14]. While physical dexterity decreased in people with thick hands and fingers, people with thin hands and fingers could do fine work more efficiently, and physical dexterity increased. Those living in cold regions are thought to adapt to these conditions with thicker hands and fingers, mainly for thermoregulation [14].

Index to Ring Finger Ratio (D2:D4)

The ratio of the index to the ring finger (D2:D4) has been the topic that most attracted the attention of scientists. Although D2:D4 differs individually or regionally, it has also been used to estimate gender, height, and weight [9]. The D2:D4 ratio has been related to personality, spatial ability, and various diseases (probably due to hormonal relationships).

The D2:D4 ratio is found to be 1.005 in Malaysians, but it is lower than 1 (<1) in other nations [58; 81]. Even though there are minimal differences in hand measurements between both hands according to hand preference, the difference between the two hands in the D2:D4 ratio is insignificant [10; 72]. Additionally, the D2:D4 ratio is lower in males than females, meaning the ring finger is longer in men than women [29; 55; 72].

Intrauterine sexual differentiation takes place towards the end of the first trimester. Thus, it has been suggested that the gender difference in the D2:D4 ratio is due to intrauterine androgen exposure during this period [13; 27; 53]. The D2:D4 ratio also differs within each gender. This difference is attributed to the variation in exposure to intrauterine sex hormones. Namely, while testosterone causes the ring finger to lengthen, contrastingly, estrogen causes the ring finger to shorten [55; 57]. In a study based on this idea, the D2:D4 ratio in male-to-female people was found to be higher than the male control group, while it was similar to the female controls [75]. These results also support the etiology of decreased prenatal androgen exposure in male-to-female people.

Males are suggested to be better at using directional cues to reach a target location in a landscape environment than females. Accordingly, the masculine D2:D4 ratio is thought to be associated with the sense of direction [21]. Physical endurance and sports performance also negatively correlate with D2:D4 [12; 35; 56; 57; 78]. Finally, the studies revealed that the personality traits of people with a male-like D2:D4 ratio are more prone to aggression, anger, violence, smoking, and problem drinking [17; 18; 24; 73].

Hands in Medicine

Many diseases present unique hand appearances specific to the condition. For example, a male-like D2:D4 pattern can be observed in patients with autism spectrum disorder and congenital adrenal hyperplasia as an indicator of intrauterine androgen exposure [15; 52; 70]. Achondroplastic patients have wide palm breadth; however, palm breadth is narrow in Marfan syndrome. The fingers are very short in achondroplasia and very long in Marfan syndrome. In Down syndrome, the hands and feet are small, and the fingers are short and wide. Patients with Down syndrome have clinodactyly (curved fingers), and arachnodactyly is present in a marfanoid appearance. In Fragile-X and Marfan syndrome, the finger joints are hyperextensible [31; 48; 54; 59; 62; 69; 76; 79; 81].

There may be changes in hand anthropometry, especially in musicians and sportspeople, because of constantly repetitive movements [83]. Also, as a result of the overuse of some joints, they may be more prone to some hand injuries [7]. Besides, due to typical hand anthropometry, some medical illnesses like Marfan syndrome may be advantageous to play specific instruments, as with Niccolò Paganini [59; 76].

In medicine, hands are also used as a measurement method to determine the landmarks of some anatomical structures or determine the instruments' estimated sizes to be used. For example, although there is a formula for calculating the pediatric endotracheal tube's diameter, the width and diameter of the little finger of the pediatric patient correspond to the endotracheal tube size suitable for the child [42]. For the femoral nerve blocks, the estimated landmark of the nerve is correlated with the distance from the femoral artery and the width of the little finger [26].

Another area where hand length is used in medicine is estimating the average body size, which is crucial in a clinical setting or forensic science if it is impossible to get specific measurements directly. Hand length and handbreadth are used to predict stature and height [37; 38; 39; 66]. Additionally, hand length is demonstrated to be an excellent independent predictor of body surface area and body mass, and it is accurate for ages two to 17, independent of gender [5; 6]. Furthermore, the hand's palmar aspect is approximately 0.78% of the body surface area [5]. Therefore, hand length is a simple measurement that can be used as a treatment guide, such as estimating the volume of intravenous fluid or packed blood cells. Furthermore, the average age of the children can be estimated by the hand and wrist X-ray, based on the knowledge that the bone maturation and ossification process continue during the child's growth [20].

The Fibonacci Sequence and Golden Ratio

The Fibonacci sequence is a series of numbers starting from 0 and 1 (0, 1, 1, 2, 3, 5, 8, 13, etc.) in which each number is the sum of the two preceding ones. In this sequence, the ratio of two consecutive numbers gives the Golden ratio of approximately 1.618 = phi (ϕ). At the same time, the Golden ratio applies to geometric shapes, such as triangles, rectangles, etc., that have this ratio between their sides. Thus, logarithmically nesting these geometric shapes suitable for this formation creates an equiangular spiral linked to many objects found in nature (nautilus shell, snail, pine cones, sunflower, etc.), architecture, music, and painting.

The esteemed hand surgeon Dr. J. William Littler is the first to discuss the adaptability of the Fibonacci sequence and Golden ratio to hands [47]. After this assertion, a study consisting of a small sample size group demonstrated that the flexion and extension path of the fingertips overlap with an equiangular spiral [28]. Subsequent studies present conflicting results, probably due to measurement differences. In studies measuring the radiographic lengths of the hand bones, the authors stated that the phalangeal ratios are different and do not follow the Fibonacci sequence [32; 67]. Following these results, which failed to prove the previous hypothesis, it has been stated that the measurement method meant by Dr. Littler is not directly measuring the actual bone lengths, but the correct measurement method should be the functional centers of the rotation lengths [60; 67] (**Fig.2**). In another study designed later on this suggestion, and it has been demonstrated that the functional lengths of the phalanges of the fifth finger do follow the exact Fibonacci sequence, while the remaining second, third, and fourth digits follow a specific mathematical pattern very similar to the Fibonacci sequence [36]. According to the results presented by a different research group, the phalanges of all five fingers cannot be ordered according to the same sequential rule [16].

Hands in Art: A Selection from the Most Famous Artists

Hand gestures reflect subtle human emotions, and hands are the most difficult to draw of all the parts of the human body. For this reason, hands have been considered one of the richest and most meaningful elements of the human body in art history and have been given a symbolic meaning. Many artists have emphasized the themes by depicting the hands in their own forms in every era. Hands have a character that offers much information about the psychological and physical condition of the owner by expressing

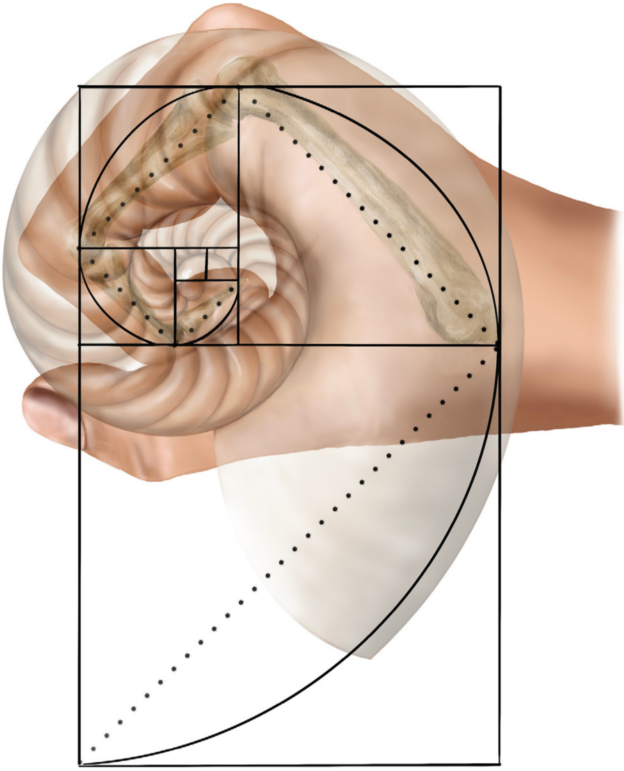

Fig. 2. A hand figure based on William Littler's hypothesis. An equiangular spiral (a nautilus shell) with the corners of the squares passing from the functional centers of rotation.

many emotions with their forms, postures, and gestures. For this reason, hands have been the focus of attention of many artists over the years.

Many nuances in similar movements of the hands can express very different or even opposite emotions. For example, a tightly flexed hand with all fingers aligned may denote someone ready to punch in a fight or a triumphant fist raised excitedly after a hard-fought victory. In contrast, a fist with fingers softly flexed to varying degrees may represent the shape of a resting hand. Again, while a hand gesture -with a taut thumb opened at a wider angle than the hand and a D2 in extension together with a tightly flexed D3, D4, and D5 in such a way that the nails are not visible- expresses a harder emotion (such as authority, tension, excitement, agitation, ...), opening the thumb with a slightly narrower angle and slightly flexing the D3, D4, and D5 with different degrees showing nails in a similar hand movement emphasizes a more natural and softer expression [22]. An example of using hand gestures with another implication is the painting of Leonardo da Vinci, in which Jesus was depicted as Salvator Mundi (Savior of the World) (1490-1500). In this artwork, the right hand with the third finger is extended next to the second finger, and the whole posture represents a blessing hand. At the same time, Leonardo da Vinci used the Golden ratio in both hands, as in many parts of the painting.

Renaissance is the period of coding and symbolism, and the artists frequently used hands and the Golden ratio in their artworks to point out their thoughts. Leonardo da Vinci is indeed one of the artists who frequently used the golden ratio in his paintings during the Renaissance period. It appears in countless places in nature and has been used in architectural structures since the time of the Egyptians. In some of his most famous paintings, such as Mona Lisa (1503), The Annunciation (1472), and The Last Supper (1495-1498), which were depicted using the Golden ratio, character and psychological analyses can be made from the gestures of the carefully drawn hands. One of the famous drawings of hands is Albrecht Dürer's painting Praying Hands

(1503). Although a praying couple of hands has been drawn, it is actually a painting of respect, devotion, sacrifice, effort, and love.

One of the most famous painters of the Renaissance period, as well as a sculptor, poet, and architect, Michelangelo di Lodovico Buonarroti Simoni's painting The Creation of Adam (1505), drawn on the ceiling of the Sistine Chapel, shows the hands of Adam and God stretching out towards each other. The purpose of the hands reaching each other here is not to shake hands or to join hands. The main subject of discussion is the space between the hands, and various theories have been produced on this. Later on, this artwork was adapted to neuroanatomy [63]. Furthermore, if we look at the Statue of David (1501-1504), one of Michelangelo's works of art, what draws our attention here is that David's right hand is incompatible with his body. The reasons behind this disproportionateness made by Michelangelo, who has worked on human anatomy for years and is a great name in body proportions and human anatomy, have been a question of debate. David's statue depicts the shepherd David, who defeated the terrible giant Goliath, an acromegaly patient, only with a tiny sling. It is thought that Michelangelo made this disproportion to emphasize David's nickname "manu fortis", in other words, "strong hand".

Art history and hand anatomy according to art periods

Renaissance, mannerism, baroque

The fact that Lorenzo Ghiberti, Antonio Pollaiuolo, and similar contemporaries began to be interested in the subject of anatomy in the early Renaissance led to the study of anatomy more frequently in the works of artists such as da Vinci, Michelangelo, and Vasari and to the production of pieces with scientific findings on the subject in the later years. At the same time, Andreas Vesalius, an anatomist, corrected the mistakes in the works of Claude Galen (Galen of Pergamon) (which has been considered valid for the last thousand years) and created the book "De Humani Corporis Fabrica Libri Septem (1543)", which was recognized as the most comprehensive scientific study on anatomy ever made to that date. The drawings and engravings in the book were made by the painters in the workshop of the famous artist of the period, Titian.

The anatomical treatment of body parts separately in art in the Renaissance period has made human hand drawings one of the indicators and criteria of concepts such as mastery and virtuosity for artists. Along with the mannerism period, which can be considered a transitional stage between the Renaissance and Baroque periods, new artistic proposals and forms were created about hand drawings and anatomy, such as exaggerating body lines and deliberately deforming them. It is possible to see the traces of Albrecht Dürer in the paintings of Hendrick Goltzius, one of the master engravers of the Early Baroque and Mannerist period, as in Peter Paul Rubens, one of the greatest painters of the Baroque period, bear traces of Hendrick Goltzius. Influenced by Michelangelo and Dürer, these two names created their unique style and form based on these artists' understanding of deformation due to the period's thought movement. Hands have become one of the most prominent indicators of this unique style in the drawings and paintings they made using exaggerated lines, form, and mass, considering each part of the human body separately. The painting of another great artist of the Baroque period, Rembrandt, "The Anatomy Lesson of Dr. Nicolaes Tulp (1632)", which depicts Dr. Tulp's lecture showing his students the muscles and bones of the human hand, has been accepted as one of the masterpieces of the period [34].

The weakening of the dogmatic thought movement of the Middle Ages and the changes experienced with the Renaissance, together with the confidence of the artists' scientific experiences in anatomy, enabled the artists to reflect the forms of the figure more freely in the Baroque and Mannerist periods.

Neoclassicism and Romantism

Hand figures and drawings from the Neoclassical and Romantic periods are a new representation of the concept of imitating nature in the forms and shapes of the classical period. In the artworks of painters such as Eugene Delacroix and Jacques Louis David, the use of figures and, therefore, hands, as a reflection of the period's intense military and political climate, seems to have undertaken a task similar to that of the classical period. In most of the paintings of Jean-Auguste-Dominique Ingres, one of the most famous portrait painters of the neoclassical period, the hands are the complements of the portrait. Due to the conditions of the period, the revival of the classical style and portraying it with surgical precision is necessary. Ingres' paintings are the most prominent examples of this. Hands and faces, which are more visible among the details and ornaments in Ingres' dull, monumental, smooth brush technique, are the last and most magnificent challenge of classicism, perhaps in the history of painting [30].

Realism

Since the mid-1800s, within the scope of the realism movement, hands have appeared differently from the fictional or symbolic style in previous periods. The hand figure is a symbol that supports the expression in artworks, mainly dealing with concepts such as religion, monarchy, and feudalism. Due to the structure of the classical period, in the realism movement, people working in the fields, greeting each other, or combing their hair are depicted as a part of real daily life in the works of painters such as Gustave Courbet and Francois Millet.

Modernism

Towards modern art, the figure begins to diverge from the classical style in the periods of Expressionism and Impressionism. Contrary to the old great ideologies and movements, when personal feelings, opinions, and self-concepts come to the fore in this period, the depiction of the figure and hands changes accordingly. Imagination forces not only the subject but also the form of the artwork. The anatomical structure is shown on the hands and the whole-body figure, with a unique deformation understanding specific to the artist. In the works of Gustav Klimt and Egon Schiele, the artists of this period, the hands are like the reflection of the feelings and thoughts of the depicted figure [46].

Cubism and surrealism

In modernism and later, the search for new ideologies and an understanding apart from formal concerns and esthetic diversity, the figure has been depicted using primitive, distorted, or geometric forms. Painters who carried out these studies, such as Picasso and Dali, the pioneers of the Cubism and surrealism movements, also made anatomic studies in their early periods; thus, they were able to distort or deform the shape in line with these classical studies. In this period, artists like Neşet Günal presented their sense of art with a social context, with deformed and disproportionately sized hands and feet.

Conclusion

Hands constitute an important place in art as well as in medicine. The shape and proportions of the hands and fingers may be typical features of people of different races living in various geographies. The shape and proportions of the hands and fingers may present the phenotype of many genetic diseases and reflect people's physical and personality traits. Additionally, hands have been considered one of the richest and most meaningful elements of the human body in art history and have been given a symbolic meaning. Many artists have depicted different emotions and events in their paintings using the characters of the hands.

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