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A Cross Sectional Study of the Relationship between Fibonacci Ratio and Trigger Finger

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ABSTRACT

Introduction: Trigger finger is one of the most common causes of hand pain in adults. The pathophysiology is unclear but inflammation and age-related degeneration have been suggested. The equiangular spiral is one of the most engaging patterns which perfectly formed flawlessly executed by transitory movement of the digits in the adaptability of the human hand. This study was done to find out the relationship between the Fibonacci ratios of the finger with trigger fingers.
Method: Forty-eight patients who had trigger finger and undergone A1 pulley released were being identified and collected. From the hand radiograph, the length of each metacarpal and proximal phalanx was measured manually. The ratio of the metacarpal bony length to the length of the respective proximal phalanx is the Fibonacci ratio of the digit.
Results: There was a significant linear relationship found between trigger finger and Fibonacci ratio ($p<0.001$).
Conclusion: Finger Fibonacci ratio significantly determines the smoothness patterns of its tendon movements.

KEYWORDS: *Fibonacci sequence, Fibonacci ratio, trigger finger, equiangular spiral.*

INTRODUCTION

The reported prevalence of trigger finger is roughly 2.2% in the general population, and is more common among women than men in the fifth or sixth decade of life (Moore JS, 2000; Shah A and Rettig ME, 2017). The person-year incidence rate was 2.6% for non-tool use workers (Gorsche R, 1998). It can occur in one or many fingers in each hand and can be bilateral. The prevalence of trigger finger is also higher among patients with diabetes mellitus, rheumatoid arthritis, or conditions that cause systemic deposition of protein such as amyloidosis (Moore JS, 2000; Saldana MJ, 2001). Trigger finger is occasionally observed in children. The most commonly affected digit is the thumb, followed by the ring, long, little, and index fingers (Fahey JJ and Bollinger JA, 1954).

One study on high-resolution ultrasound examination performed in 20 trigger fingers (no thumb recruited) and 20 normal contralateral digits (Chuang XL, et al., 2017). It found that, during full finger flexion, the greater thickening of the FDS tendon bifurcation will move proximally beyond the proximal end of the A1 pulley, which in this region that leads to the sticking or triggering problem. However, the thumb does not consist of flexor digitorium superficialis (FDS) tendon but the thumb is among the commonest digit which is triggering. Although the patient may have diabetes mellitus (DM), aging degenerative process or have underlying hypothyroidism or gout, but why one of his or her finger is higher predominantly affected than the others?

"The Motion Path of the Digits", as described by Gupta A et al. (1998), which had verified evidence of digital motion executing an equiangular spiral. The path of the finger during flexion and extension closely follows that specific pattern which allows unrestricted grasp and release. The normal unrestrained arc of flexion and extension arc of the fingers are consistent with this equiangular spiral and it is one of the most intriguing designs in nature. Deviations from this equiangular spiral may help in recognition of conditions that interfere with normal hand function such as arthritis or hand injuries. The lengths of the metacarpals and phalanges are related intimately to their motion path in flexion and extension (Park AE et al., 2003). For their motion to follow the equilateral spiral, the phalangeal and metacarpal bone lengths would theoretically need to follow the Fibonacci relationship because the 2 are mathematically linked by the Fibonacci rectangles (Littler JW, 1973).

The Fibonacci series is a sequence of integers, starting with 0 and 1, and proceeding as such that the next number is equal to the sum of the preceding 2, thus 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, and so forth. The ratio of each 2 adjacent numbers, 1/1, 2/1, 3/2, 5/3, 8/5, 13/8, 21/13 and so forth, approaching but never quite reach the value of 1.618, closer and closer in an oscillating manner, to infinity. Therefore, the mathematicians, architects, artists, physicists, and biologists have been interested in the intrinsic properties of this irrational number. This ratio has been reputed to be ubiquitously found within nature, including the spirals of the galaxies, seashells, flowers and DNA structure. Importantly, it has been suggested to be found in human structures, including the hand and heart (Coldea R et al., 2010). The ultrastructure of our human hand and heart are made up by this intricate proportional relationship and sequential cytoskeletal and myofibrils proteins aggregations, respectively (Jason YS Chan and GH Chang, 2009). The propensity for this ratio to appear in nature may be because this ratio optimizes the efficiency of packing structures in a limited space in such a way that wasted space is minimized and the supply of energy or nutrients is optimized (Gibson et al., 2003). Deregulation of the underlying patterning law may manifest as variation in hand-heart structure away from that as would be determined by the golden ratio. Besides that, deviation or interruption from this ratio in hand-finger proportion could possibly correlate with similar clinical implications in terms of disease screening and risk prediction (Jason YS Chan and GH Chang, 2009).

This led us to think about whether the bony phalangeal and metacarpal length of the fingers will predispose the finger to trigger because of the deviation from the equiangular spiral as well as the Fibonacci ratio. The aim of this study was to find out is there any relationship between the Fibonacci ratios of the finger anatomical length with trigger fingers.

METHODOLOGY

The patients who had confirmed to have trigger finger and had underwent A1 pulley released were being identified and collected from the registration books in the Day-care operation theatres (OT) as well as the Elective and Emergency General OTs. All of the trigger finger released patients are recruited from January 2014 to June 2018 and the patients' demographic data were recorded in the data collection form.

Patients who having multiple triggers fingers in one hand, previous trauma or fracture of the triggered finger phalanges or metacarpal, previous infection in the hand or fingers, previous Ray's amputation or congenital deformities, skeletal immaturity and joint contracture over finger were excluded from the study. In additional, patients who do not have proper hand postero-anterior (PA) radiographic film and no thumb proper anterio-posterior (AP) radiographic film were also excluded from the study.

For those patients who have the hand radiographic film, the mid-axial (mid-diaphyseal) line will be drawn manually on each metacarpal and phalanx. The length of the each metacarpal and proximal phalanx was measured manually by orthopaedic medical officers and recorded (in millimetres). The mid-axial length of the each bone is measured from the distal end of the articular surface (head) to the proximal end of the articular surface (base). The ratio of the metacarpal bony length to the length of the respective proximal phalanx will be the Fibonacci ratio of the finger and thumb. Even though different patient hand radiograph films have different magnification, the result of the ratio of each finger is numerical unit.

One study had identified that the ring finger is the most prevalent trigger finger (35.2%), followed by the thumb (31.5%), the long finger(27.8%), the index finger (5.6%) and 0 for the little finger (Makkouk AH et al., 2008; Shah A and Rettig ME, 2017). The incidence of the ring finger, thumb, and long finger together accounted for almost 95% of the trigger digits. This study found that no strong association between trigger finger and comorbidities, such as diabetes or hypothyroidism.

RESULTS

A total of 48 patients with trigger finger were recruited in this study with range from 37 to 71 years old and mean age 56.54 ± 8.11 years old (Table 1). Majority of the patients were female (70.8%). The patients recruited for this study were from three different ethnic groups which were Malay (66.7%), Chinese (22.9%) and Indian (10.4%). Majority of the subject were right hand dominant (95.8%) but the distribution of the hand in which the finger had triggering were almost the same for left (47.9%) and right hand (52.1%). From the 48 patients, 20.8% with trigger thumb, 8.3% with triggering index finger, 22.9% with triggering long finger, 47.9% with triggering ring finger and none of them have triggering little finger. The premorbid of the patients were identified in this study where half of the patients were diagnosed with diabetes mellitus, 2.1% had gout and 47.9% without any premorbid.

Table 1: Characteristics of respondents

	Frequency (percentage)	**Mean (sd)**
Age		56.54 (8.11)
Gender		
Male	14 (29.2)	
Female	34 (70.8)	
Ethnic		
Malay	32 (66.7)	
Chinese	11 (22.9)	
Indian	5 (10.4)	
Dominant hand		
Right	46 (95.8)	
Left	2 (4.2)	
Trigger finger		
Thumb	10 (20.8)	
Index	4 (8.3)	
Long	11 (22.9)	
Ring	23 (47.9)	
Little	0 (0.0)	

Triggered hand* Right Left	 25 (52.1) 23 (47.9)	
Premorbids Diabetes mellitus Gout No premorbids	 24 (50.0) 1 (2.1) 23 (47.9)	

*The hand of the trigger finger.

Ten triggering thumbs and 38 not triggering thumbs were identified in the study. The mean Fibonacci ratio of triggering thumb and not triggering thumb were 1.53 ±0.07 and 1.56 ± 0.10 respectively (Table 2). The independent t-test showed no significant different of mean Fibonacci ratio between triggering thumb and not triggered thumb. (p=0.370). Only four triggering index finger were identified in the study (n=48). The mean Fibonacci ratio of triggering index finger and not triggering index finger were 1.72 ±0.09 and 1.66 ± 0.08 respectively. No significant different of mean Fibonacci ratio between triggering index finger and not triggered index finger were found (p=0.176).

Out of 48 long fingers, 11 of them were diagnosed with triggering finger. The mean Fibonacci ratio of triggering long finger was 1.42 ±0.07 and 1.44 ±0.07 for not triggering long finger. No significant different of mean Fibonacci ratio between triggering long finger and not triggered long finger were found (p=0.602). Besides that, 23 triggering ring finger and 25 not triggering ring finger were compared in this study. The mean Fibonacci ratio of triggering ring finger and not triggering ring finger were the same (1.35 ±0.07). There is no significant different of mean Fibonacci ratio between triggering ring finger and not triggered ring finger (p=0.890).

No little finger was diagnosed with triggering finger in this study. Therefore no comparison can be done. The mean Fibonacci ratio for little finger was 1.56 ± 0.07.

Table 2: Mean Fibonacci ratio for each finger

Fibonacci Ratio	**Mean (sd)**	**Mean difference (95% CI)**	***t-statistics (df)**	**p-value**
Thumb trigger finger not triggering finger	 1.53 (0.07) 1.56 (0.10)	-0.03 (-0.10, 0.04)	-0.91 (46)	0.370
Index trigger finger not triggering finger	 1.72 (0.09) 1.66 (0.08)	0.06 (-0.03, 0.15)	1.37 (46)	0.176
Long trigger finger not triggering finger	 1.42 (0.07) 1.44 (0.07)	-0.01 (-0.07, 0.04)	-0.53 (46)	0.602
Ring trigger finger not triggering finger	 1.35(0.07) 1.35 (0.07)	-0.00 (-0.04, 0.04)	-0.14 (46)	0.890
Little trigger finger not triggering finger	 - 1.56 (0.07)	-	-	-

*independent t-test was applied.

The association between independent factors and Fibonacci ratio for all trigger digits were determined by using simple linear regression as showed in Table 3. There were significant linear relationship found between trigger finger and Fibonacci ratio ($p<0.001$). The mean Fibonacci ratio of triggering finger and not triggering finger were 1.44 ± 0.13 and 1.53 ± 0.13 respectively. There was no significant linear relationship found between the Fibonacci ratio with patient's age, gender, ethnic, underlying premorbid and hand dominance. A triggering finger had 0.10 unit of Fibonacci ratio lower than a not triggering finger (mean difference -0.10, 95% CI -0.14, -0.06). Multiple linear regression analysis was proceeding with variables which had p-value <0.250 and showed that only triggering finger was significantly associated with Fibonacci ratio after adjusted with all other confounders. The Fibonacci ratio could be predicted lowered by 0.10 units in the trigger finger.

Table 3: Associate factors of Fibonacci ratio using simple linear regression

Variables	Mean (sd)	Regression coefficient, b (95% CI)	t-stat	p-value
Age		0.001(-0.002, 0.003)	0.59	0.555
Gender				
Male	1.53 (0.14)	0		
Female	1.51 (0.13)	-0.02 (-0.06, 0.02)	-1.11	0.269
Ethnic				
Malay	1.51 (0.13)	0		
Chinese	1.53 (0.14)	0.02 (-0.02, 0.06)	0.94	0.346
Indian	1.52 (0.13)	0.005 (-0.05, 0.06)	0.19	0.851
Premorbid				
No	1.51 (0.13)	0		
Diabetes Mellitus	1.51 (0.14)	-0.005 (-0.04, 0.03)	0.29	0.773
Gout	1.54 (0.14)	0.03 (-0.09, 0.15)	0.48	0.634
Dominant Hand				
Right	1.51 (0.14)	0		
Left	1.49 (0.14)	-0.02 (-0.11, 0.07)	-0.45	0.650
Triggering finger				
No	1.44 (0.13)	0		
Yes	1.53 (0.13)	-0.10 (-0.14, -0.06)	-4.63	<0.001

*Simple Linear Regression was applied.

DISCUSSION

The majority of trigger fingers are idiopathic. The pathogenesis of trigger finger is mostly unclear and some observational reports suggesting an association with occupational or repetitive activities, but this are somewhat controversial. The precise pathobiology of tenosynovium in trigger fingers is also unclear. The main histopathological finding at the first annular (A1) pulley is fibrocartilaginous metaplasia of the tendon sheath with secondary reduction in the cross-sectional area of the fibro-osseous canal (Sbernardori MC and Bandiera P, 2007). In 2014, K. Uchihashi et al. reported that inflammatory infiltrate in only 37% (14 specimens) of trigger fingers. This laboratory study had identified chondrocytoid cells that produce hyaluronic acid and a hypocellular collagen matrix in the tenosynovium of trigger finger, suggesting that excess hyaluronic acid synthesis and an edematous swollen collagen matrix are involved in the progression of trigger finger.

There is a mathematical harmony between human finger phalanges bones with each respectively metacarpals in terms of the Fibonacci sequence for smooth gripping or make a fist. The functional lengths of the phalanges and metacarpal of the little finger do follow actual Fibonacci series and it explained why little finger rarely gets triggered (Alan and Richard, 2010; Yilmaz A, 2010) (Table 1). In comparison of the mean Fibonacci ratio of each individual digit, there is no significant different of mean ratio between trigger finger and not triggering finger (Table 2). However, by using linear regression tests, the current study found out that there is significant linear association between Fibonacci ratio and trigger finger (p<0.001) but do not have significant linear relationship with the patient's age, gender, ethnic, underlying premorbid and hand dominance (Morsi DA and Hawary AA, 2013) (Table 3).

The efficiency of packing structures in a limited space in finger flexor tendon sheath and its energy or nutrients supply are optimized by this Fibonacci sequential digital length. Each of the ring and the middle finger metacarpophalangeal joint (MCPJ) are connected by deep transverse metacarpal ligament (DTML) on both radial and ulna sides whereas the index and the little only have one DTML on ulna and radial sides respectively (Kaplan EB and Spinner M, 1984). Besides that, there are present of two bipennate dorsal interosseous and two unipennate palmar interosseous musculotendinous structures passed thru on each radial & ulna sided of the ring and the middle finger MCPJ. This cause limited space for the packed flexors to glide efficiently and getting adequate energy and nutrients. Repetitive motions in edematous collagen matrix leading fibrocartilaginous metaplasia of the tendon sheath. At the volar surface of the thumb MCPJ, there have one thumb adductor, two sesamoids and 3 intrinsic thenar musculotendinous units, this limited and packed space may possibly correlates with higher predisposition or risk in getting flexor stenosing tenosynovitis (Jason YS Chan and GH Chang, 2009).

The motion arcs of the joints during digital flexion are consisting of a series of circles with a progressively decreasing radius. Flexor tendon motion within the sheath involves continuous angular gliding over a series of cruciate and annular pulleys, synovial sheath and the volar plate. Not only are pulleys and sheath over the joint curved along with joint angulation, but the curvature of the pulleys over the proximal and middle phalanges were increased with flexion of the fingers (Lin GT et al., 1989; Zhao CF et al., 2000). Because movements of the finger are constantly a process of tendon glide over the sheath with changing curvature, therefore the relationship between the nature of a gliding curve and changes in tension on the tendon is variable for all tendons undergoing finger motion (Tang JB et al., 2003). When the tendon is tensioned angularly over a pulley, the tendons are subjected to both an angular tensile load and a compressive load (the bending force). Different in the gliding curvature create a differential loading on both the superficialis and profundus flexor tendons. In relatively stenotic sheath, this differential gliding of both flexors will catch and resulting in mechanical impingement.

In finger kinesiology and biomechanic, there is indirect participation of the finger extensors during normal finger flexion (Kaplan EB and Spinner M, 1984). Such agonistic-antagonistic coactivation creating forces exerted at the tendons and consequently at the same time creating stretches on the opponent tendons (Beek N., 2018). Tendon displacements in the fingers will probably not only be the result of finger tendon movement, but also of tendon stretch. Thus, higher tendon displacements during active finger flexion compared to passive finger flexion, despite equal ranges of finger movement, have previously been described (Korstanje J.W. et al., 2010) as finger enslaving. In all four fingers, besides the common extensor tendons, the index finger and little finger are having Indicis Proprius tendon and Digiti Minimi tendon, respectively. The long and short extensors of the thumb also exerted as antagonist for the flexors in the highly-mobile thumb in different plane of motions. The presence of discrepancy tendon stretch by this anatomical factor during active and passive finger movements may also contribute for a certain finger to have more predisposed to get trigger finger.

LIMITATIONS

Radiographic assessment of trigger finger usually not required because the diagnosis can be made by characteristic findings in the history and physical examination. Therefore, the patients who did not have hand or thumb x-ray films are excluded from this study. This will eventually cause the amount of the sample size getting smaller. Studies on the radiographic parameters of normal adult hands were adequate (Alan and Richard, 2010; Yilmaz A, 2010; Morsi DA and Hawary AA, 2013) and having a hand radiograph investigation on a typical trigger finger patient is practically unethical. In this current study, the patients who have radiographic hand assessment were those who have finger night pain or associated joints pain at other body parts

CONCLUSION

The observation of the Fibonacci sequence is existent in almost all aspects of life ranging from the leaves of a fern tree, architecture, and even paintings, makes it highly unlikely to be a stochastic phenomenon. This sequence optimizes the finger in such a way that wasted space is minimized in the propensity of repetitive motions in a packed space (Gibson et al., 2003). The current study found that the Fibonacci ratio could be predicted lowered by 0.10 in the trigger finger. By demonstrating an equiangular spiral in hand movement, we can now understand that conditions interfere with normal hand function.

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