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Mathematical Relations between the Lengths of the Metacarpal Bones and Phalanges: Surgical Significance

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AYDINLIOĞLU, A., AKPINAR, F. and TOSUN, N. *Mathematical Relations between the Lengths of the Metacarpal Bones and Phalanges: Surgical Significance.* Tohoku J. Exp. Med., 1998, **185** (3), 209 216 —— The mathematical relationship between the lengths of the metacarpals and phalanges is important in hand surgery because of its role in determining the lengthening of the tubular bone size or the length of a prosthesis. The purpose of the present study is to perform the measurements on the hand radiographs, and to determine possible mathematical relations between the lengths of the metacarpals and phalanges. The lengths and widths of metacarpals and phalanges were measured in millimeters on hand roentgenograms of 100 normal voluntary subjects (50 men, 50 women) and the results were evaluated with a descriptive analysis test. The relations between the lengths of the metacarpals and phalanges were mathematically investigated on several sets of data. Unchangeable proportions between the metacarpals and phalanges lengths were found and formulated. Because any defects or faults of the hand, especially shortness, can corrected with current improved surgical techniques, a knowledge of the morphometric relations between the lengths of metacarpals and phalanges may be useful for such surgical interventions. ——— metacarp; phalanges; radiographic measurements

Both functionally and aesthetically, hands are among the most important organs for human beings. They have a perfect anatomical harmony between tissues and are thus capable of successfully performing even the most intricate activities. Any kind of congenital or acquired defects in the bone or soft tissues of the hands may cause both functional and aesthetical failures. Shortness of bones in the hand, especially in the metacarpals, may be an indication of a disease or a syndrome. Such syndromes and the disorders associated with the shortness of the metacarpals have been reported (Gorman et al. 1962; Tuomaala and Haapanen 1968; Pfeiffer and Weber 1974; Sybert et al. 1976; Isozaki et al. 1984; Tamburrini 1985).

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Recently, as a consequence of the widespread and successful practices of microsurgery of the hand, functional and aesthetic faults have been reduced. The tissues in the hand have to be reformed to an ideal anatomical configuration to obtain perfect functional results. Short tubular bones are the basic structural elements of the hand, and the knowledge about their lengths is of great help in reestablishing the ideal anatomical harmony. The purpose of this study is to perform the measurements on the hand radiographs, and to determine the possible mathematical relations between the lengths of the metacarpals and the phalanges. By measuring the lengths and the widths of metacarpals and phalanges, we aimed at finding out the mathematical relations among them. It was expected that if an association between the lengths of the metacarpals and phalanges was found, it may be useful in determining the lengthening of the metacarpal and phalangeal bone size or the length of a prosthesis.

Materials and Methods

Selection of materials

The materials for the present study were obtained from voluntary adults with an equal sex distribution (50 males and 50 females). Their ages ranged from 20–40 years old. The subjects were routinely exposed to x-rays. Subjects with a history of trauma or surgery in the hands were excluded. The films were screened for readability. Radiographs showing evidence of degenerative changes were also excluded. All radiographs were taken with a standardised radiographic technique from 100 cm distance. The hands were x-rayed in anteroposterior position with the wrist in neutral position and fingers extended. The x-ray beams were centered on the hands and an anode-film distance of 100 cm was maintained. The magnification resulting from the use of this technique was negligible.

Measurements

For the purpose of the present study, hand radiographs obtained from 100 (50 males and 50 females) volunteer healthy subjects were used. To determine the lengths of metacarpals and phalanges, their head and base were taken as the limits. The mid points of these limits were first marked on the radiograph (A and B). A line between these points was drawn proximodistally for each metacarpal and phalangeal length. A perpendicular line defining the width was extended from this line at the halfway point for each metacarpal and phalangeal bone (CD). Measurements were made directly from the radiographs using a sliding vernier caliper. The readings were recorded to the nearest 0.1 mm. The following measurements of the bones were made: Metacarpal lengths (AB) and widths (CD), proximal phalangeal lengths and widths, middle phalangeal lengths and widths, distal phalangeal lengths and widths (Fig. 1). The mean and standard deviations of the lengths and widths of metacarpal and phalanges were calculated. To investigate mathematical relations between the lengths of the metacarpals and the

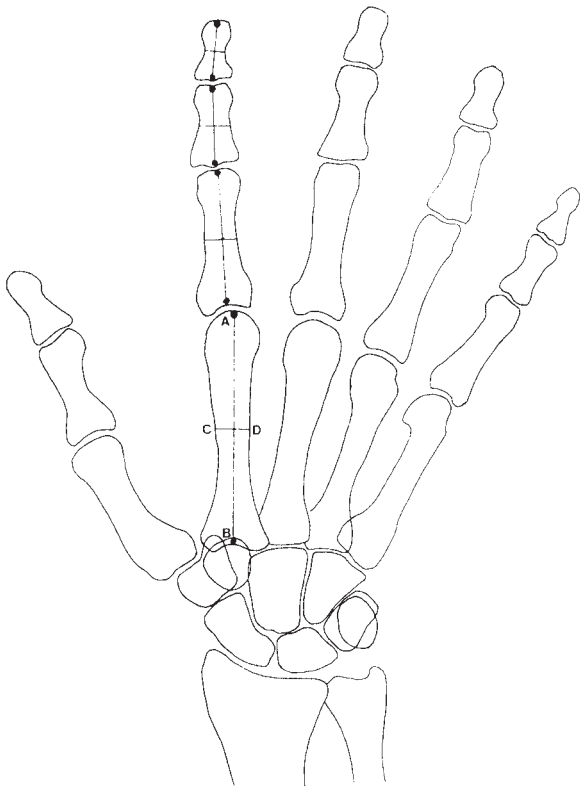

Fig. 1. Diagram showing the position of markers for measuring the metacarpals and phalanges. *AB*, metacarpal and phalangeal lengths; *CD*, metacarpal and phalangeal bone widths (2. phalanges are only termed for explanation).

phalanges, separate calculations were used for each bone and proved their conclusions statistically correct.

Results

In the results of the calculations, we found unchangeable proportions between the metacarpals and between phalanges lengths, and formulated there in Tables. Our results were found to be statistically correct (goodness of fit for normal distribution, $\text{cv} = \text{S.D.}/\bar{X} < 0.33$). The relations of the metacarpals and phalanges concerning the lengths were as follows:

Metacarpal relations

1. Metacarp length $= 0.67 \times 2$. Metacarp length $= 0.71 \times 3$. Metacarp length $= 0.78 \times 4$. Metacarp length $= 0.84 \times 5$. Metacarp length. See Table 1 for Metacarp 2, 3, 4, 5.

Proximal phalangeal relations

1. Prox. Phal. length $= 0.67 \div 2$. Prox. Phal. length $= 1.49 \div 3$. Prox. Phal. length $= 1.38 \div 4$. Prox. Phal. length $= 1.06 \div 5$. Prox. Phal. length. See Table 2 for the relations of proximal Phalanx 2, 3, 4, 5.

TABLE 1. *The proportions of metacarpal lengths in comparison with each other**

1. Metacarp	2. Metacarp	3. Metacarp	4. Metacarp	
÷0.67				=2. Metacarp length
÷0.71	÷1.06			=3. Metacarp length
÷0.78	÷1.16	÷1.10		=4. Metacarp length
÷0.84	÷1.26	÷1.19	÷1.08	=5. Metacarp length

* Note that, for example; 5. Metacarp length=1. Metacarp length/0.84, or 2. Metacarp length/1.26, or 3. Metacarp length/1.19, or 4. Metacarp length/1.08
Similary, apply the formula to other metacarp lengths.

TABLE 2. *The proportions of proximal phalangeal lengths in comparison with each other***

1. Prox. Phalanx	2. Prox. Phalanx	3. Prox. Phalanx	4. Prox. Phalanx	
×1.33				=2. Prox. Phalanx length
×1.49	×1.12			=3. Prox. Phalanx length
×1.38	×1.03	×0.93		=4. Prox. Phalanx length
×1.06	×0.79	×0.71	×0.77	=5. Prox. Phalanx length

** Note that, for example; 1. Proximal Phalanx length×1.33=2. Proximal Phalanx length

Middle phalangeal relations

2. Mid. Phal. length=1.17÷3. Mid. Phal. length=1.11÷4. Mid. Phal. length=0.82÷5. Mid. Phal. length. See Table 3 for the relations of middle phalanx 3, 4, 5.

Distal phalangeal relations

1. Dist. Phal. length=0.82÷2. Dist. Phal. length=0.86÷3. Dist. Phal. length=0.87÷4. Dist. Phal. length=0.78÷5. Dist. Phal. length. See Table 4 for the relations of distal phalanx 2, 3, 4, 5.

Table 5 summarizes the lengths of metacarpals and phalanges and Table 6 summarizes the widths measured from the middle of the lengths of metacarpals and

TABLE 3. *The proportions of middle phalangeal lengths in comparison with each other****

2. Mid. Phalanx	3. Mid. Phalanx	4. Mid. Phalanx	
×1.17			=3. Mid. Phalanx length
×1.11	×0.95		=4. Mid. Phalanx length
×0.82	×0.70	×0.74	=5. Mid. Phalanx length

*** Note that, for example; 2. Middle Phalanx length×1.17=3. Middle Phalanx length

TABLE 4. *The proportions of distal phalangeal lengths in comparison with each other*****

1. Dist. Phalanx	2. Dist. Phalanx	3. Dist. Phalanx	4. Dist. Phalanx	
×0.82				=2. Dist. Phalanx length
×0.86	×1.05			=3. Dist. Phalanx length
×0.87	×1.06	×1.01		=4. Dist. Phalanx length
×0.78	×0.95	×0.91	×0.90	=5. Dist. Phalanx length

**** Note that, for example; 1. Distal Phalanx length×0.82=2. Distal Phalanx length

TABLE 5. *Descriptive analysis of the metacarpal and phalangeal bone lengths in both genders*

	Age. 20–40		Mean (mm)		S.D.		Min		Max	
	F(n)	M(n)	F	M	F	M	F	M	F	M
1. Metacarp	50	50	42	46	2	3	38	41	48	52
2. Metacarp	50	50	63	68	4	4	47	60	70	77
3. Metacarp	50	50	60	64	3	4	53	55	68	72
4. Metacarp	50	50	54	58	3	4	48	50	61	65
5. Metacarp	50	50	50	54	3	4	41	40	56	61
5. Prox. Phalanx	50	50	30	34	3	2	21	30	35	38
5. Mid. Phalanx	50	50	18	20	3	2	14	15	29	23
5. Dist. Phalanx	50	50	15	17	1	1	13	15	18	20
4. Prox. Phalanx	50	50	39	43	3	3	31	38	44	48
4. Mid. Phalanx	50	50	25	28	2	2	20	20	29	32
4. Dist. Phalanx	50	50	17	19	1	1	15	16	20	23
3. Prox. Phalanx	50	50	42	46	3	3	37	40	47	52
3. Mid. Phalanx	50	50	27	29	2	2	20	23	32	33
3. Dist. Phalanx	50	50	17	19	1	1	15	16	20	23
2. Prox. Phalanx	50	50	37	41	2	3	33	37	42	45
2. Mid. Phalanx	50	50	22	24	2	4	20	20	27	45
2. Dist. Phalanx	50	50	16	18	1	1	14	15	18	20
1. Prox. Phalanx	50	50	28	31	2	2	22	26	32	35
1. Dist. Phalanx	50	50	20	23	2	2	15	15	25	26

F, Female; M, Male; S.D., Standartd deviations.

phalanges analyzed by descriptive methods.

DISCUSSION

Since it is now possible to reestablish the lengths of extremities to ideal anatomic size by the widespread use of improved surgical techniques, it is important to have a knowledge of the ideal anatomical length for reshaping the

TABLE 6. *Descriptive analysis of the metacarpal and phalangeal bone widths in both genders*

	Age. 20–40		Mean (mm)		S.D.		Min		Max	
	F(n)	M(n)	F	M	F	M	F	M	F	M
1. Metacarp	50	50	9.4	11	0.7	0.7	8	10	11	13
2. Metacarp	50	50	8	9.5	0.5	0.7	7	8	9	11
3. Metacarp	50	50	8.2	8.9	0.6	0.5	7	8	10	10
4. Metacarp	50	50	6.6	7.6	0.6	0.8	6	6.5	8	9.5
5. Metacarp	50	50	7.3	8.8	0.5	0.6	6.5	7.5	8	10
1. Prox. Phalanx	50	50	8.1	9.5	0.6	0.07	7	8.5	9	11
1. Dist. Phalanx	50	50	5.8	7.2	0.7	1.0	5	6	7.5	10
2. Prox. Phalanx	50	50	9.1	10.6	0.7	0.7	8	9	11	12
2. Mid. Phalanx	50	50	7.5	8.6	0.5	0.6	7	7	9	10
2. Dist. Phalanx	50	50	4.6	5.3	0.5	0.4	4	4.5	5.5	6
3. Prox. Phalanx	50	50	9.4	10.9	0.7	0.8	8	10	11	13
3. Mid. Phalanx	50	50	8.3	9.9	0.6	0.8	7	8	9	12
3. Dist Phalanx	50	50	4.9	5.7	0.4	0.4	4	5	6	6.5
4. Prox. Phalanx	50	50	8.6	10.1	0.7	1	7.5	8	10	12
4. Mid. Phalanx	50	50	7.8	9.3	0.6	0.7	7	8	9	10
4. Dist. Phalanx	50	50	4.7	5.5	0.4	0.5	3.5	4.5	5	6
5. Prox. Phalanx	50	50	7.6	9	0.7	0.8	6.5	8	9	11
5. Mid. Phalanx	50	50	6.3	7.7	0.6	0.5	5	7	7.5	9
5. Dist. Phalanx	50	50	3.6	4.4	0.3	0.4	3	4	4	5

F, Female; M, Male; S.D., Standard deviations.

metacarpals and phalanges with shortness resulting from various causes. In the present study, the mathematical relations between the metacarpals and phalanges were found by means of calculation, for the first time (Tables 1, 2, 3 and 4). These findings were later substantiated in practice on the radiographs. Measurements of hand bones have already been evaluated by different methods and noteworthy studies in this area have been reported (Bloom 1970; Cervantes et al. 1988). In the present study, we determined the second metacarp as the longest and the first metacarp as the shortest. This conclusion agrees with the literature (Williams et al. 1989).

Shortness in one or more of the hand bones may indicate a sign of a syndrome or a disease. Shortness of the first metacarp is associated with radial aplasia (Strauch and Spinner 1976; Dobyns et al. 1988). More than 1 mm metacarpal shortness creates weakness in grasping and difficulty in making a hard fist due to failure of the metacarpal arc (Dobyns et al. 1988). The strength of grasping is reduced in the metacarpal shortness due to fractures (Workmen 1964). Gropper and Bowen (1984) offered open reduction and internal fixation in metacarpal

fractures with shortness exceeding 2 millimeters. The shortness caused by angulation and displacement in the phalangeal fractures results in aesthetic and functional faults.

Recently any defects or faults of the hand, especially, shortness, can be corrected with improved surgical techniques. It is clear that a knowledge of the lengths of metacarpals and phalanges in comparison with other metacarpals and phalanges is important for such a surgical intervention. So we determined some unchangeable proportions between the metacarpal lengths, and between phalanges, that can facilitate calculation of the lengths of any other metacarpals or phalanges from a known length of metacarp or phalanx.

In conclusion, the relations from the present study may be of pragmatic interest to the orthopaedic surgeon. This data may be useful for bilateral multiple metacarpal shortening for lengthening the digits. Proportions we found suggested that if the length of a metacarp or phalanx is known, the others could be calculated nearly to the ideal anatomical configuration. In the cases which need the original length for cosmesis or function, such cases commonly have an intact opposite hand. So the other hand is good to give an optimal length in case of unilateral disease and trauma. On the other hand, for application of prosthesis this data is useful for bilateral multiple defect to decide the proper length of each finger of prosthesis.

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