THE EVALUATION OF FINGER MOBILITY IN THE FRONTAL PLANE

by

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The aim of this paper was to evaluate finger mobility of the human hand in the frontal plane. Active mobility of the metacarpophalangeal joints from the 2nd to 5th finger and the mobility of the thumb was evaluated on the basis of drawings performed in two variants. This method may be applied in physiotherapy. The most representative variables describing this phenomenon were chosen. The research was conducted on 424 subject (168 males and 256 females) between the age of 20-23 years. Greater mobility was detected the frontal plane in the non-dominant hand. In case of all measured variables greater values were reached by females.

Introduction

The literature related to the human hand is numerous and relates to the structural issues (Pagowski and Piekarski 1977, Hager-Ross and Schieber 2000, Jansen and wsp. 2000, Zatsiorsky and wsp. 2000) and problems of mobility and forms of grasping (Nadolski 1977, Mallon et al. 1991, Skvarilova and Plevkova 1996, Blackwell et al. 1999). It should be also mentioned that especially broad is the research data concerning functional changes and evaluation methods of the hand under different dysfunction (Klimek 1986, Pieniążek et al. 1987, Pieniążek 1991, Cytowicz-Karpiłowska and Seyfried 1994, Butler et al. 2000, Hosseini et al. 2000).

Biomechanical research of the hand relate to joint mobility and manipulative possibilities. The data in this area is rather scarce and the proposed research methods as well as obtained data are controversial. In case of finger

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mobility evaluation especially in regards to adduction (metacarpophalangeal joints from the 2nd to 5th finger) in control testing the distance between extended finger tips is used (Zembaty 1989). This method of evaluation among adults allows for individual diagnosis of rehabilitation process and progressiveness of dysfunction yet it does not allow to compare interpersonal comparisons in subjects of highly differentiated hand and finger size. The possibilities of comparisons exists only in these cases when mobility is evaluated on the basis of angular measures which are independent of linear values.

The evaluation of angular values with the use of traditional goniometers is unprecise and difficult to conduct because of the difficulties with establishing the axis of turn (Carey et al. 1988, Zembaty 1989). When measuring the mobility with the use of goniometer in the mentioned joints Wise et al. (1990) registered significant measurement errors regardless of the used apparatus. The application of x-rays method is difficult and inconvenient in case of frequent evaluations, great number of subject and fast data collection.

This justifies the attempt of creating a new simple and reliable method of finger mobility evaluation in the frontal plane which allows multiple use. The main aim of this paper is development of such a method and diagnosis of hands health in aspect of its mobility. The acquired data may be used as comparative material for researchers in this area.

Material and methods

The research was conducted on 424 subject (168 males and 256 females) between the age of 20-23 years. The measurements were preceded by evaluation of hand lateralization which showed that 147 males and 236 females were right-handed. The average body mass and height were 1,81±0,06 m and 76,1±9,11 for males while 1,67±0,06 m and 58,1±6,24 kg for females.

In evaluating hand mobility the range of motion was determined under conditions of adduction (frontal plane) in metacarpophalangeal joints from the 2nd to 5th finger. The choice of these joints was not accidental since they play a decisive role in determination of hand working area which creates hand working space.

As a measure of active mobility of the mentioned joints the angular values were accepted between long axes of fingers. These angles were measured on hand drawings (shape) which were performed in two procedures: A and B. Shape A was the contour of the hand with maximal, active adduction of the thumb and little finger. The consequence of the mentioned adduction of distal fingers was the structure of other fingers (the value of angles between them). The scheme of type A outline is presented in figure 1. In second procedure (outline B) the angular values of adjacent fingers (Ist with IInd, IInd and IIIrd etc.) during maximal, active adduction were registered, what was presented in figure 2.

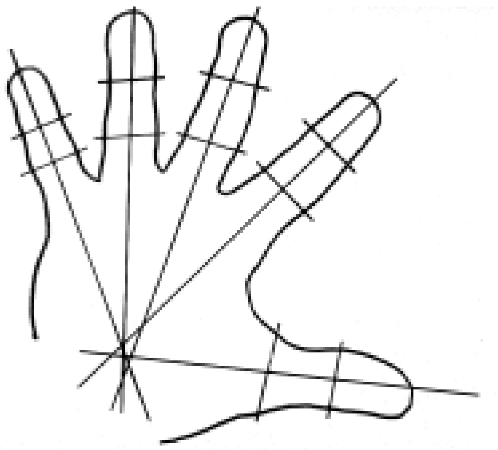

Fig. 1. Left hand outline of male (type A)

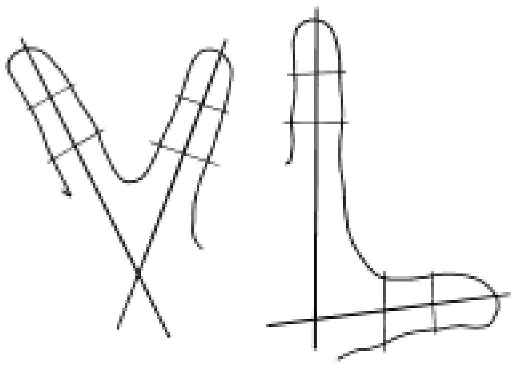

Fig. 2. Outlines type B: index and middle fingers (angle II, on left) and thumb and index (angle I, on right)

Before the hand outlines were done the tested subjects performed short warm-up which included mainly flexibility exercises of the fingers. The outlines were drawn with the thin marker which was placed perpendicularly to the paper. Outlines allowed to exclude four angles between following fingers:

a) angle I – thumb and index finger,
b) angle II – index and middle finger,
c) angle III – middle and ring finger,
d) angle IV – ring and little finger.

On the basis of the outlines type A the following variables were obtained:

a) angles between particular fingers (∢I, ∢II, ∢III, ∢IV),
b) angle between thumb and little finger treated as hand working area in the frontal plane (∢I-V).

Additionally, the input of particular angular values in the adduction of distant fingers was expressed in percent values ($P_{\%}I$, $P_{\%}II$, $P_{\%}III$, $P_{\%}IV$).

The outlines type B were used for determination of maximal angular values of adjacent fingers of both hands. (I_{max}, II_{max}, III_{max}, IV_{max}).

The obtained angular values were processed statistically with the use of STATISTICA v. 5.1. software. Basic descriptive statistics were calculated. The significance of difference between the average values of chosen variables was determined by the Student t-test. All acquired values were expressed in angular measures [deg], while the input of particular angles in relative values [%].

Results

The results presented in table 1 indicate that in both sexes hand working area of the non-dominant hand is on the average 2,5% greater than in dominant hand and this difference is statistically significant in females ($p \leq 0,05$). The values of ∢I-V are in case of both hands smaller in males.

Table 1. Descriptive statistics of hand working area (∢**I–V)** at the measured groups: **M** – male **F** – female, $\overline{x}$ – mean value, **SD** –standard deviation, **R** – range, **min** – minimum, **max** – maximum, **V**- coefficient of variation, [a] – significant difference between both hand work areas (p<0,05).

	Hand	$\overline{x}$ ±SD [deg]	R [deg]	min [deg]	max [deg]	V [%]
M	**Dominant**	107,1±13,6	80,0	66,0	146,0	12,7
	Non-dominant	109,8±13,5	78,0	66,0	144,0	12,3
F	**Dominant**	109,2±13,8 [a]	69,0	75,0	144,0	12,6
	Non-dominant	111,9±14,3 [a]	81,0	70,0	151,0	12,8

The variables calculated on the basis of the outline type A are in case of both sexes almost identical for both hands (table 2). The angular values of adjacent fingers and their inputs hand working area ($P_{\%}$) have similar character: the highest values are registered for angle I and respectively IV, II and III.

Table 2. The angles between long axes of fingers measured on the outline type A (M - male, F - female) $\mathbf{P_{\%}}$ – the input of particular angle in hand working area.

		M		**W**	
hand	**angle**	$\overline{x}$ ±SD [deg]	$P_{\%}$ [%]	$\overline{x}$ ±SD [deg]	$P_{\%}$ [%]
dominant	I	50±10,6 [b]	46±7,3 [c]	46±10,9	42±7,6
	II	20±5,2 [c]	18±4,6 [b]	22±6,0	20±5,2
	III	14±4,7 [b]	14±4,3 [a]	16±5,3	15±4,7
	IV	23±5,6 [b]	22±4,6 [b]	25±6,3	23±5,3
non dominant	**I**	50±11,0 [b]	45±7,2 [c]	47±11,2	42±7,5
	II	20±5,1 [c]	18±4,4 [c]	22±6,0	20±4,8
	III	15±4,9 [b]	14±4,3 [b]	17±5,0	15±4,4
	IV	24±5,2 [b]	22±4,3 [a]	26±6,1	23±5,0

Statistical significance: [a] p<0,05. [b] p<0,01. [c] p<0,001.

It is possible to state that all sexual differences in calculated variables are statistically significant. The higher values were reached in relative and absolute variables in females excluding ∢I.

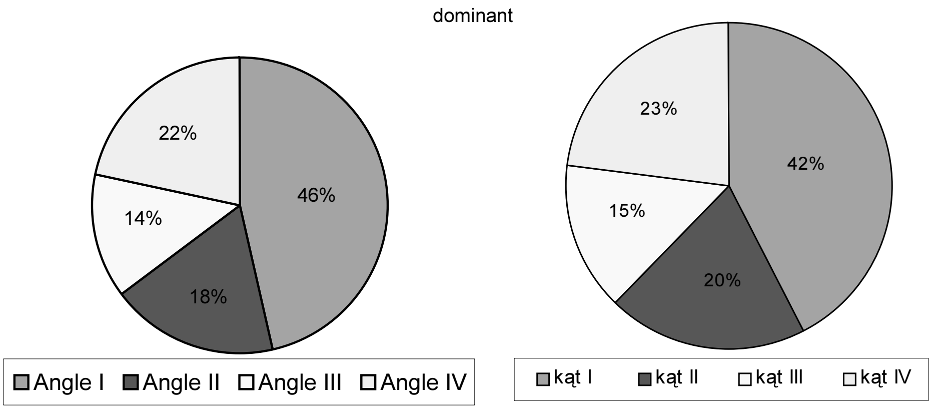

Fig. 3. The percentile input of angles ($P_{\%}$) between fingers (type A) in the measure of hand working area (∢I-V) of dominant hand (male – left, female – right)

The highest angular values of adduction of two adjacent fingers (type B) always related to the thumb and index finger (∢I). They equaled 76 to 81°, while the remaining angles were significantly smaller and reached values of 34-40° (II_{max}), 25-30° (III_{max}) and 32-38° (IV_{max}). The lowest values of presented measurement were always characteristic for males (fig. 4). The acquired sexual differences in maximal angular values created by long axes of adjacent fingers are statistically significant, excluding I_{max} ($p<0,05$).

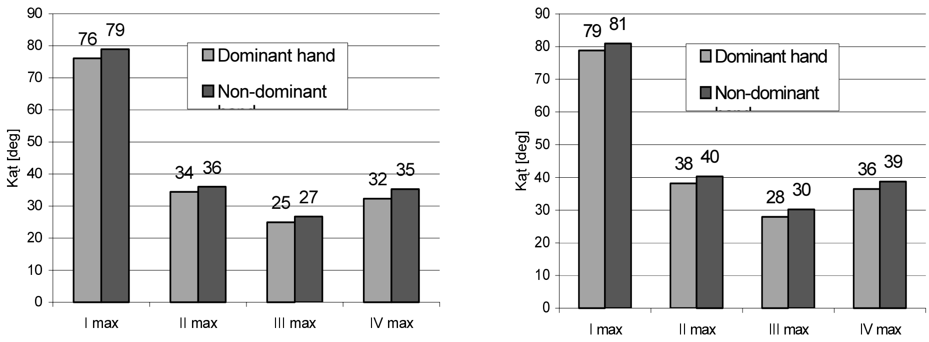

Fig. 4. The maximal angular values between adjacent fingers (type B) in males (left) and females (right)

The measurements of angles in outline type B indicate greater mobility of non-dominant hand joints, and in case of II_{max}, III_{max} and IV_{max} these differences are statistically significant in both sexes ($p<0,01$).

Discussion

Hand working area in all planes is equal to the smallest area of the smallest figure including extrapolation of all points of the hand to a particular plane. The size of this area is dependent upon biokinematic pairs. One of the methods of increasing the hand working area is based on adduction in metacarpophalangeal and saddle joints.

The angle of adduction of distant fingers (∢I-V) measured for the purpose of this work may be treated as a measure of the hand working area in the frontal plane, independent of linear hand measures. During the extension of the fingers this area is smallest when all the fingers are connected (hand working area is approximately equal to the area outlined by the fingers and wrist). The adduction of any number of fingers increases the hand working area by the area included between those fingers.

The amount of possible grasps, especially their quality are dependent on hand mobility, so the range of motion of adduction in metacarpophalangeal joints are of primary importance. Proposed in this paper method of determining the mobility of particular hand joints treated as a whole is a consequence of observations made by researchers. Bochenek and Reicher (1997) in their fundamental work presented the range of adduction in metacarpophalangeal joints in fingers II-V in angular values. More recent data do not contradict these results however they underline the objective problems associated with reliable evaluation of mobility in these joints in the frontal plane. Zembaty (1989) stated that the measurement of adduction angles of fingers II-V in metacarpophalangeal joints is impossible because of difficulty in choice reference points and the existence of multijoint movements in this measurements. Similar opinions were expressed by Hager-Ross and Scheiber (2000), explaining this fact by passive mechanical relationships among fingers and multitendon organization and neuromuscular control of finger muscles.

Zaciorski et al. (2000) qualified this structural organization of particular fingers into one system called the "enslaving effect" existing in an equal degree in the dominant and non-dominant hands. Reilly and Hammond (2000), Norkin and Levangie (1992) have noticed that the range of adduction in the metacarpophalangeal joints reaches maximal values during full extension in these joints in the sagittal plane, what is obviously related to the anatomical construction of this body part, especially to the tension of ligaments (Bochenek and Reicher 1997). Due to the difficulties in evaluation of the range of motion in hand joints the values presented by particular researchers differs significantly yet it is obvious that the greatest mobility is characteristic for the metacarpophalangeal joints of fingers II and V, and is smaller in case of fingers III and IV (Bochenek and Reicher 1997, Hager-Ross and Schieber 2000, Mallon et al. 1991). Simultaneously, the analysis of the available literature allows to state that the values presented by Bochenek and Reichert (1997) are significantly overestimated due to a small number of subjects, or due to the fact that the data was collected on the human skeleton.

The method of evaluation of hand mobility applied in this work is similar to the method presented by Chiu et al. (2000). However these authors measured only the area of particular finger movements obtaining information on angular changes in finger joints and determining the percentile decrease of this area in subjects after surgery.

The use of the outlines for the determination of hand mobility were suggested earlier by Ruchlewicz and Staszkiewicz (1998). The proposed then methodology did not change, yet different variables were considered as representative. It seems that, from a practical point of view (for scientific purposes) the description of finger mobility in the frontal plane may be performed with the use of following variables: in outline type A - ∢I-V and percentile input of particular angles in hand working area ($P_{\%}$), while in outline type B – maximal adduction angle of adjacent fingers (I_{max}, II_{max}, III_{max}, IV_{max}).

The measured value of angle ∢I-V equals to 110° and is slightly higher in females. This result is also influenced by the functional asymmetry (lateralization). The lack of statistically significant differences and the level of mobility of the dominant and non-dominant hand in healthy subjects is confirmed by data of Hager-Ross and Schieber (2000), as well as Mallon et al. (1991). In contradiction to the cited authors, Skvarilova and Plevkova (1996) reveal small yet significant differences in the range of adduction in metacarpophalangeal joints of the left and right hand. It seems that last statement can not be accepted since the mentioned research was conducted on selected subjects (200 right-handed subjects).

As mentioned previously, the maximal measures of hand working area in the frontal plane of females and males obtained in this research do not differ significantly. This indicates similar joint mobility responsible for this types of movement for both sexes. Similar conclusions are presented by Bochenek and Reicher (1997), Mallon et al. (1991), Norkin and Levangie (1992), however contradictory opinions exist (Skvarilova and Plevkova 1996). The conclusions from Skvarilova and Plevkova (1996) are probably related to a greater variability of female results, what was mentioned by Mallon at al. (1991), yet it is not confirmed by the results of this paper.

The inputs of particular angles ($P_{\%}$) in the hand working area for the left and right sides are identical, however higher values of (P%I) were registered in females. In case of both sexes the smallest values of ($P_{\%}$) were registered for angle III (between middle and ring finger) and this result is in accordance with data presented by Bochenek and Reicher (1997) and Norkin and Levangie

(1992). These authors determined the range of adduction in metacarpophalangeal joints of these fingers as the smallest.

Maximal values of adduction of adjacent fingers in healthy subjects are always greater on the non-dominant side (2-3°) and additionally greater mobility was registered in females (3-5°). The mentioned differences are statistically significant. These results are similar to those of Skvarilova and Plevkova (1996) which proof the lack of differences of mobility of the right and left hand. Authors suggesting small differences in this area (Hager-Ross and Schieber 2000, Mallon et al. 1991, Norkin and Levangie 1992) would probably arrive to similar conclusions if their research projects would be conducted on a greater number of subjects.

Conclusions

The results of the conducted research and their analysis allow to formulate the following conclusions:

1. The proposed method of mobility evaluation of the hand (outline type A and B) is a simple and reliable tool that can be applied in physiotherapy.
2. The most representative variables include ∢I-V and $P_{\%}$ in case of outline type A and I_{max}, II_{max}, III_{max}, IV_{max} in outline type B.
3. The sex and direction of lateralization of the tested subjects influences the value of all significant variables, describing the mobility of the hand in the frontal plane.

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