The Conjugacy of Some Anthropometric Parameters with the Strength of the Brush and the Load Distribution on Its Zones

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Abstract: - The aim of this study was to estimate the relationship of the anthropometric parameters of an individual with the strength of the hand and the nature of the load distribution in its various zones when performing a cylindrical grip in practically healthy individuals. Anthropometric parameters and the results of biomechanical examination of both hands were analyzed in 78 practically healthy individuals (39 men, 39 women) of the most able-bodied age (from 19 to 50 years). The height and weight of the volunteers were measured using a manual electronic dynamometer "Jamar Smart" – the strength of the right and left hands (in kilograms). The dynamometry of the hand was performed in a sitting position, while the arms of the subject were located on the armrests, the elbow was bent at an angle of 90°, the forearm was in a neutral position, and the hand was in the extension position in the wrist joint at an angle of about 30°. The anthropometric characteristics of the hand were recorded by measuring (in cm) the lengths of the rays of the hand and fingers, and the length and width of the palm. Determination of the degree of load on various parts of the brush (as a percentage) was carried out using the hardware and software complex "Teksan" (USA). It is established that the strength of the brush depends on the anthropometric characteristics of the individual and its linear dimensions: the "longer" and "wider" the brush, the higher its strength indicators. When performing a cylindrical grip, the maximum load falls on the fingers, among which the I-IV are the most involved, to a lesser extent – the V finger and the tenar area. It was revealed that the load distribution indicators for different zones of the right and left hand differ: when performing a cylindrical grip with a weaker brush, the main load falls on the tenar area and the first finger. At the same time, the achievement of maximum grip with a weaker brush is achieved by the maximum involvement of small hand muscles in the process.

Key-Words: - anthropometric parameters, biomechanical examination, the hand, tenar, muscles.

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1 Introduction

Strength and coordinated coordination of movements of the flexor muscles of the hand and forearm are necessary for the implementation of the entire range of daily human activities, [1]. The execution of all kinds of grips by the brush, which causes its subtle manipulative function, is possible only if there is a certain synergy of the muscles of the hand and forearm, [2]. However, as a result of injuries and diseases of the upper limb, surgical interventions performed, prolonged immobilization, and the friendly action of the muscles of the hand and forearm may be disrupted. Muscle imbalance leads, in turn, to a decrease in the strength of the hand, and changes in the load on its various departments, which must be taken into account when building adequate rehabilitation programs. If various manual dynamometers are widely used to register the strength of the hand, then technologies and equipment of the company "TekScan" (USA), which have not yet found wide application in our country, are used to study the load distribution on various departments of the lower and upper extremities. There are more and more articles in the foreign literature devoted to the results of the application of this technology in practical medicine.

At the same time, only a few works concern the peculiarities of load distribution on the hands and upper extremities, [3], [4], [5], [6]. However, these studies did not concern the study of the influence of gender differences and anthropometric characteristics of the brush on the nature of load distribution in its various zones. The question of the dependence of the grip force and the peculiarities of load distribution on different areas of the brush remains open.
The purpose of the study was to estimate the relationship between the anthropometric parameters of an individual with the strength of the hand and the nature of the load distribution in its various zones when performing a cylindrical grip in practically healthy individuals.

2 Materials and Methods

Anthropometric parameters and the results of biomechanical examination of both hands were analyzed in 78 practically healthy individuals (39 men, 39 women) of the most able-bodied age (from 19 to 50 years).

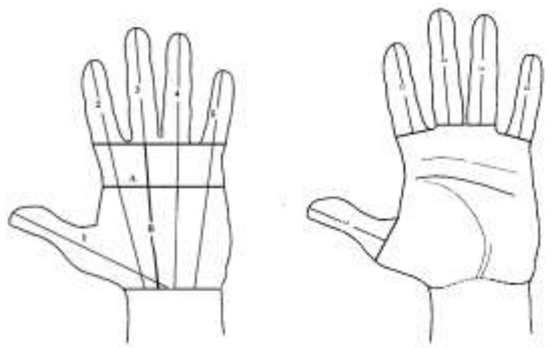

Fig. 1: 1 – the length of the I ray – the distance from the tip of the I finger at its maximum retraction to the middle of the distal palmar fold; 2,3,4,5 - the length of the I, II, III, IV, V rays – the distance from the tip of the finger at its maximum retraction and to the projection point of the proximal end of the metacarpal bone on the distal palmar fold; L1, L2, L3, L4, L5 -- the length of the fingers (the distance along the middle line from the tip of the finger to its base); A – the width of the palm (the distance corresponding to the transverse palmar fold); B – the length of the palm (the distance from the middle of the base of the III third finger to the middle of the distal palmar fold); 3 B –the length of the hand, which corresponded to the length of the III beam.

The height and weight of the volunteers were measured using a manual electronic dynamometer "Jamar Smart" – the strength of the right and left hands (in kilograms).

The dynamometry of the hand was performed in a sitting position, while the hands of the subject were located on the armrests, the elbow was bent at an angle of 90°, the forearm was in a neutral position, and the hand was in the extension position in the wrist joint at an angle of about 30°.

It is proved that in such a position the maximum compression force of the brush is achieved, [7]. The subject used each brush to compress the dynamometer three times for 3-5 seconds, after which the average force values were recorded.

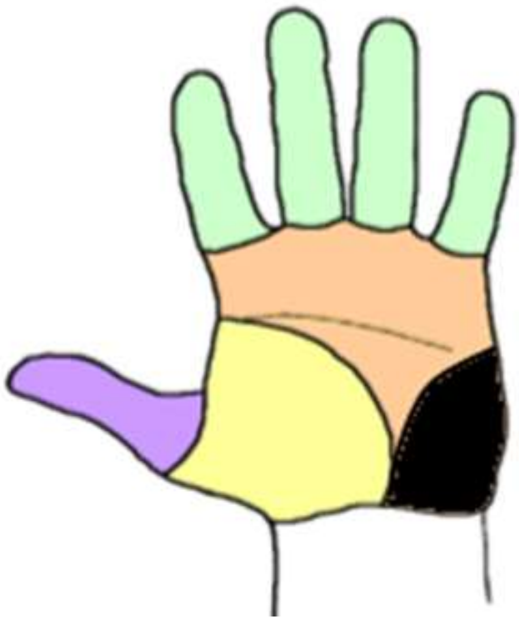

Fig. 2: Studied areas of the brush

The anthropometric characteristics of the hand were recorded by measuring (in cm) the lengths of the rays of the hand and fingers, and the length and width of the palm (Figure 1). Since all the examined were right-handed, measurements were carried out the dominant (right) hand, while the right and left hands were considered as symmetrical figures, [8]. The length of the palm was defined as the difference between the length of the third ray and the third finger. Determination of the degree of load on various parts of the brush (as a percentage) was carried out using the hardware and software complex "Teksan" (USA). The patient wore gloves with ultra-thin bar sensors applied to certain areas. The sensors were located on the nail, middle and main phalanx of the fingers, the area of the tenar and hypotenar, the middle part of the palm, which made it possible to register pressure on these areas of the hand (Figure 2). The patient, at the command of each brush, alternately squeezed a cylinder with maximum force for two seconds, the diameter of which was selected individually, so that when During the capture, the I finger formed a "ring" and came into contact with other fingers. At this time, signals from sensors were recorded. A color image of the pressure distribution of the brush on the support surface of the cylinder and the values of the compression force were obtained on the monitor screen (Figure 3).

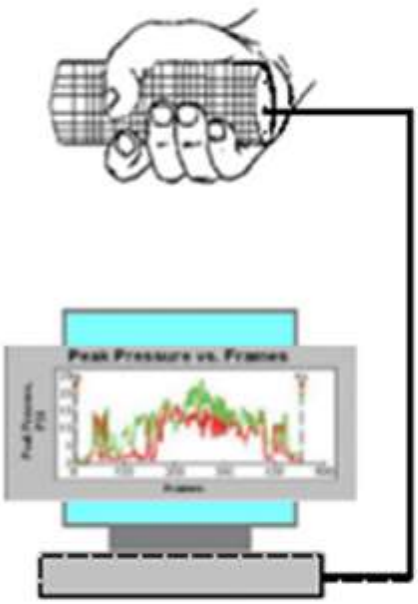

Fig. 3: The scheme of determining the load on different areas of the brush

The analysis of the obtained results was initially carried out for the entire contingent of volunteers, then separately for men and women.

Methods of nonparametric statistics (Mann-Whitney and Wald-Wolfowitz criteria, Spearman's rank correlation coefficient) were used to process the obtained results. When describing the data obtained, the following were used: mean value (M), standard deviation (σ), mean error (m), median (Me), and first and third quartiles [25%;75%]. The critical level of statistical significance is assumed to be 0.05.

3 Results and Discussion

The average anthropometric indicators of 78 surveyed volunteers were: age – 28.1±0.8 [19;48] years, height -171.6±1.0 [153;190] cm, weight - 70.5±1.7 [46;120] kg.

Table 1. Anthropometric parameters of the brush and their dependence on height and weight

Anthropometric parameters	**M±m(cm)**	**r¹**	**r²**
Palm width	8,4±0,08	0,62	0,53
Palm length	10,3±0,07	0,67	0,42
Length of the I beam	13,1±0,09	0,55	0,35
Length of the II beam	17,5±0,1	0,55	0,40
Length of the III beam	18,2±0,1	0,65	0,46
The length of the IV beam	16,9±0,1	0,58	0,47
V beam length	14,5±0,1	0,57	0,46
Length of I finger	6,6±0,08	0,53	0,47
The length of the II finger	7,1±0,06	0,43	0,38
Length of the third finger	7,9±0,06	0,50	0,39
IV finger length	7,3±0,06	0,46	0,33
V finger length	5,8±0,05	0,39	0,31

Note: r1 is the correlation coefficient with the right brush; r2 is the correlation coefficient with the left brush

The indicators of height and weight correlated with each other (r=0.72), and in women this relationship was less pronounced (r=0.33) than in men (r=0.52). The relationship we have identified between the weight indicators and the individual's height is not new. The interdependence of these parameters is confirmed by numerous literature data, where these indicators were taken to calculate body mass indices as certain prognostic criteria for the development of obesity, [9], [10], [11].

When calculating for the entire population examined, it was found that the strength of the right (42.2±1.5kg; Me=37.3kg) and left (39.6±1.5kg; Me=37.8kg) hands did not significantly differ (p>0.05). On the one hand, the absence of differences in the strength of the right and left hands contradicts the widespread opinion that the dominant hand is in many cases 3.0-22.6% stronger than the non-dominant one, [12], [13], [14], on the other hand, confirms the data about the fact that almost 11% of right-handed people have equal strength indicators of their hands, [15].

The relationship between the strength of both hands and the age of the volunteers was weak (gpr = 0.36; glev = 0.36). In our opinion, this is due to the age homogeneity of the volunteers, who were all younger than 50 years (Me=23.0 years), and a decrease in the strength indicators of the hand can be expected at a later age, [16], [17].

Table 2. The dependence of the strength of the brush on its anthropometric characteristics

Anthropometric parameters	r¹	r²
Palm width	0,49	0,49
Palm length	0,53	0,54
Length of the I beam	0,41	0,41
Length of the II beam	0,38	0,40
Length of the III beam	0,50	0,52
The length of the IV beam	0,48	0,50
V beam length	0,42	0,45
Length of I finger	0,36	0,34
The length of the II finger	0,26	0,28
Length of the third finger	0,36	0,38
IV finger length	0,37	0,38
V finger length	0,29	0,30

The relationship of these indicators was more clearly traced with the height and weight of the examined – the correlation coefficients were 0.69 and 0.65 for the right hand, respectively, and 0.67 and 0.62 for the left.

Table 3. Distribution of the load on different areas of the brush when calculating for the entire contingent

Brush areas	M±m (%)	Me
The upper part of the palm	11,7±0,4	11,5
Tenara region	11,5±0,4	11,7
Hypotenar region	8,8±0,3	8,9
The whole palm	31,9±0,6	32,0
The first finger	13,5±0,4	12,4
The second finger	15,9±0,3	15,7
The third finger	18,4±0,4	17,9
The fourth finger	14,5±0,3	14,1
The fifth finger	8,0±0,2	8,0
All fingers (II-V)	55,5±0,6	55,1

A similar dependence was found in the examination of 422 people, [18]. In addition, similar data were obtained on a sample consisting of 151 men and 152 women aged 18 to 25 years, as well as in a study conducted on 134 young athletes, [19], [20].

There was no correlation between the linear dimensions of the brush and the age of the subjects – the correlation coefficient for all parameters was 0.005.

At the same time, the correlation analysis showed a close relationship between the anthropometric characteristics of the hand and the height of a person, and, to a lesser extent, his weight (Table 1).

A relationship was established between the strength of the hand and its linear characteristics – the length and width of the palm, and the length of individual rays (Table 2). This relationship was less pronounced with the length of the II and V fingers. The interdependence of the power of the brush (especially dominant!) Some foreign authors have also discovered the anthropometric characteristics of the upper limb, [21]. It should be noted, however, that the revealed correlations concerned mainly the size of the forearm, and the linear parameters of the hand, only the width of the palm was recorded.

An analysis of the load distribution on various areas of the hand, regardless of gender and the side of the study, showed that when performing a cylindrical grip, the maximum load falls on the fingers, among which the most involved are I-IV, to a lesser extent – V finger (Table 3).

Table 4. Load distribution on different zones of the right and left-hand M±m (%)

Brush areas	Right hand (n=78)		Left hand (n=78)	
	M±m (%)	Me	M±m (%)	Me
The upper part of the palm	12,2±0,4	11,6	11,4±0,5	11,4
Tenara region	9,3±0,4	9,2	13,6±0,5	13,9
Hypotenar region	8,8±0,4	8,9	8,8±0,4	8,8
The whole palm	30,3±0,8	29,9	33,6±0,7	33,1
The first finger	12,5±0,5	11,6	14,6±0,5	14,0
The second finger	16,6±0,5	16,2	15,2±0,3	14,9
The third finger	21,1±0,5	20,6	15,7±0,4	15,4
The fourth finger	14,6±0,4	13,9	14,5±0,4	14,3
The fifth finger	8,2±0,3	8,0	7,8±0,2	7,9
All fingers (II-V)	57,4±0,7	57,2	53,4±0,7	53,4

The tenar zone accounts for 36.1% of the load experienced by the palm when implementing a cylindrical grip.

In our opinion, the dependence of the strength of the hand on its linear dimensions and the nature of the distribution of the load on its zones are due to the peculiarities of the participation of the muscles of the hand and forearm when performing a forceful grip. The main role in its implementation is played by M.M. flexores digitorum superficialis et profondus and M.M. interossei. All tenar muscles take part in the capture, and especially the m. adductor pollicis brevis and m. flexor pollicis longus, contributing to the blocking of the capture by flexing the distal phalanx of the I finger. The thumb, together with the tenar, supports and provides counter-pressure to the pressure of the other four fingers on the object, which helps to increase the grip force.

Table 5. Anthropometric indicators of volunteers

Anthropo-metric parameters	**men (n=39)**	**Me**	**women (n=39)**	**Me**
Age	30,6±1,1	29,0	25,6±1,2	23,0
Height	178,4±0,8	178,0	164,8±0,9	164,0
Weight	81,4±1,5	79,0	59,7±1,9	58,0
The power of the right-hand	54,6±0,8	54,8	29,9±0,6	31,1
The power of the left-hand	51,6±0,9	51,4	27,7±0,7	27,7
Palm width	8,8±0,1	8,8	8,1±0,05	8,0
Palm length	10,6±0,09	10,5	10,0±0,06	10,0
Length of the I beam	13,5±0,1	13,4	12,8±0,1	12,8
Length of the II beam	18,0±0,2	18,0	17,2±0,1	17,2
Length of the III beam	18,8±0,2	18,8	17,7±0,1	17,6
The length of the IV beam	17,5±0,1	17,7	16,4±0,1	16,3
V beam length	15,0±0,1	15,0	14,1±0,1	14,1
Length of I finger	6,9±0,1	6,9	6,3±0,1	6,3
The length of the II finger	7,3±0,1	7,5	7,0±0,1	6,9
Length of the third finger	8,1±0,1	8,2	7,7±0,1	7,6
IV finger length	7,5±0,1	7,5	7,0±0,1	7,0
V finger length	6,0±0,1	6,0	5,7±0,1	5,7

The grip is optimal, and its strength is maximum when the thumb touches or approaches the index finger, forming a single stop that resists the pressure of four other fingers, [22]. At the same time, the role of the V beam in the performance of power capture seems minimal. Therefore, the longer the length of the brush rays, the larger its dimensions, the higher the developed grip force, and the greater the load on the corresponding zones.

Table 6. Load distribution on different areas of the right and left hand in men

Brush areas	**Men (n=39)**			
	Right hand		**Left hand**	
	M±m (%)	Me	M±m (%)	Me
The upper part of the palm	11,8±0,6	11,1	11,9±0,6	11,5
Tenara region	10,7±0,5	10,6	14,1±0,6	14,1
Hypotenar region	10,3±0,6	10,3	9,9±0,4	9,8
The whole palm	33,1±1,3	32,8	35,6±0,8	35,0
The first finger	12,6±0,8	11,7	14,5±0,8	14,0
The second finger	17,0±0,8	17,0	15,0±0,5	14,9
The third finger	20,4±0,7	19,8	15,4±0,8	15,0
The fourth finger	14,2±0,7	13,3	14,1±0,7	13,2
The fifth finger	9,1±0,4	8,7	7,5±0,4	7,2
All fingers (II-V)	54,8±1,1	53,3	52,9±1,1	52,9

The load distribution indicators on the right and left hands differed (Table 4). On the left hand, when performing a cylindrical grip, the greatest load fell on the tenar area and the first finger. The load on the fingers, including II and III, was lower.

It can be assumed that in the implementation of the forceful grip of the left (weaker!) with the brush, the main load falls on its internal muscles and tenar muscles, which have to "compensate" for the weakness of the forearm muscles.

Gender differences in anthropometric characteristics and the distribution of load on the areas of the hand were investigated. Men were taller and larger than women and had higher strength indicators of both the right and left hand – $p<0.01$ (Table 5).

The data obtained by us correspond to the results of foreign authors, [23], [24], [25].

In both women and men, the anthropometric characteristics of the hand practically did not affect its strength indicators: the correlation coefficients were in the range from -0.11 to -0.32 and from -0.04 to -0.23, respectively.

Table 7. Load distribution on different areas of the right and left hand in men and women

Brush areas	**Women (n=39)**			
	Right hand		**Left hand**	
	M±m (%)	Me	M±m (%)	Me
The upper part of the palm	12,4±0,6	11,8	10,8±0,8	9,7
Tenara region	8,3±0,7	7,8	13,3±0,9	13,4
Hypotenar region	7,3±0,5	6,7	7,9±0,6	6,7
The whole palm	27,8±0,8	27,8	31,8±1,1	31,8
The first finger	12,4±0,7	11,2	14,5±0,8	13,1
The second finger	16,0±0,6	15,3	15,3±0,5	14,9
The third finger	21,7±0,6	20,7	15,6±0,5	15,6
The fourth finger	14,9±0,4	14,1	14,9±0,5	14,8
The fifth finger	7,5±0,3	6,9	8,1±0,3	7,9
All fingers (II-V)	59,8±0,8	59,4	53,9±1,0	53,9

If we take into account the fact that when calculating the entire contingent of the surveyed, the interdependence of these indicators ensured the predominance of the strength and size of the hand in men, then the absence or weakness of the relationship in gender groups, in our opinion, is explained only by a small number of observations.

The indicators of load distribution on different zones of the right and left hand differed (Table 6 and Table 7). In women and men, when performing a cylindrical grip with the left hand, which was weaker, the main load fell on the tenar area and the first finger. If we take into account that the forearm muscles on the non-dominant hand are 10.2% weaker, [26], it can be assumed that when performing a cylindrical grip with the left hand, small hand muscles are maximally involved in the process: worm-like, tenar and first finger muscles, the strength of which largely depends on gender, weight body, and hand dominance, [27].

The linear dimensions of the brush and its segments did not affect the quantitative indicators of load distribution, both for men and women – the maximum values of the correlation coefficient did not exceed 0.3.

4 Conclusion

1. The strength of the brush depends on the anthropometric characteristics of the individual and its linear dimensions: the "longer" and "wider" the brush, the higher its strength indicators.
2. When performing a cylindrical grip, the maximum load falls on the fingers, among which the I-IV are the most involved, to a lesser extent – the V finger and the tenar area.
3. Load distribution indicators for different zones of the right and left hand differ: when performing a cylindrical grip with a weaker brush, the main load falls on the tenar area and the first finger.
4. The achievement of maximum grip with a weaker hand is achieved by the maximum involvement of the small muscles of the hand in the process.
5. Various kinds of fibroplastic processes, the consequences of injuries associated with the defeat of the muscles of the hand, will lead to a change in the nature of the distribution of load on its various zones, which must be taken into account when drawing up adequate rehabilitation programs (the use of directed stimulation of the muscles of the hand (especially tenar) and forearm, classes on devices with biofeedback, the selection of specific exercises motor therapy).

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- Marina I. Shchedrina: Investigation, Formal analysis, and Writing – original draft and Writing – review & editing.
- Andrew K. Martusevich: Formal analysis and Writing – original draft and Writing – review & editing.
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Conflict of Interest
The authors have no conflicts of interest to declare.