POSSIBLE EXPLANATION OF THE “10% RULE” IN MANUAL ASYMMETRY, BASED ON THE MUSCLE STIFFNESS IN VIVO

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This research is devoted to the justification of the classical “Rule of 10%” due to one selected hand muscle (First Dorsal Interosseous - FDI). This rule has been initially established for the integrated maximum voluntary contraction of the full range of grip muscles. In the experiment we used the model of contraction based on the abductive action. It was shown that the "10% rule” may be due to stiffness of skeletal muscle elements. Essential statistical relationships between the stiffness of FDI and its strength at maximal voluntary isometric contraction were found. This study has confirmed the “Rule of 10%” for bilateral generation of force by a single FDI muscle. This research establishes grounds for a critical attitude to the use of maximum force measurement technique for testing handedness.

Key words: Indices of Hardness, Compression, Stiffness, Deformation

Introduction

One of the most typical tests for clinical identification of manual asymmetry is measurement and comparison of voluntary grip force, developed by both hands. A number of authors note that the right hand of right-handers usually has a greater level of dexterity, however, approximately in 10% of cases the dominant hand grips a lesser force than subdominant [2,9,10] This phenomenon is called "rule of 10% [2, 9,10,18].

As is known, the maximum isometric grip force is a complicated issue, because it involves more than 20 muscles of the hand and forearm [20]. The known studies of asymmetry of force generated by individual identical muscles of both hands gives quite contradictory results [7]. Only some studies confirm the validity of extending the "Rule of 10%” to selected hand muscles [18]. A serious drawback of all of these studies is the small number of subjects, which makes it impossible for serious statistical conclusions about the validity of this rule in terms of generation of maximal force by solitary hand muscles. In turn, this prevents the physiological rationale for this rule.

The aim of this paper is an attempt to explain the “rule of 10%” in terms of the influence of biomechanical properties of skeletal muscle tissue on generation of muscle strength**.** One of the key biomechanical indices of musculoskeletal tissue is the value of its hardness. According to Watkins [20] the stiffness of the muscle tissue means the energy of its resistance to the linear or volumetric deformation. Watkins theoretically suggested that the a stiffer muscle would be able to develop a greater effort. However, we have not found experimental verification of this theory in the literature. We hypothesized that perhaps in some cases, the wrist muscles of his left hand in right-handers have a greater stiffness (rigidity) because they have more muscle fibers of larger diameter, enclosed in a dense endomysium shell [1, 6, 16].

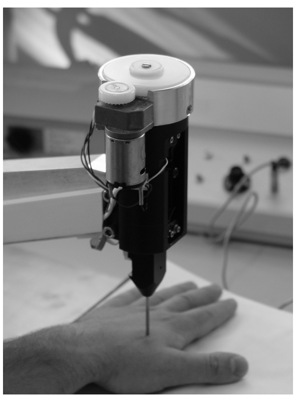
Objects and methods of investigation.

The studies were conducted in the experimental lab of Unitec (Auckland, New Zealand) after the approval by the local ethics committee. The investigation was conducted on the First dorsal interosseous muscle (FDI), which is a classical model in a number of physiological studies [3, 5, 8, 14, 16-19]. This muscle is involved in both actions: flexion and abduction of the index finger [3, 11, 20]. We investigated only abduction of this muscle because this component has been used by previous researchers to explain the “rule of 10%” [8, 17-19].

Initially we calculated the level of right-handedness using the method of Oldfield [15]. 55 strongly right-handed, healthy, untrained young men, aged from 18 to 28 years old, with laterality quotient +85 and higher were selected for this experiment.

Experimental Procedure

The first part of the experiment included the determination of isometric force, produced by the FDI using a standard ring dynamometer with accuracy ±0,01 N [5, 11, 14, 16]. A subject pressed the ring sensor at the level of the proximal intraphalangial joint of his index finger, which he tried to move in a medial direction using maximum voluntary effort as described in the standard classic experiments [5, 11, 14, 16]. For each hand we recorded three



values of maximum force using 5 minutes intervals to avoid muscle fatigue (6 tests for each participant).

The second part of the experiment was related to the compression of the big belly of FDI, which is clearly visible above the surface of the skin, in a vertical dorsal-ventral direction. This allows to precisely record the force, deflection and time of compression of the muscle using a standard elastometer, previously described in our work (see fig 1) [12, 13].

Fig. 1 General view of the apparatus for the measurement of stress-strain behaviour of muscle

The touch sensor head of this device was immersed in the belly of muscle with external force generated by a special mechanical drive. At every 0.05 mm of deflection the resistive force of muscle and real-time of immersion of the sensor were plotted on-screen via computer. Maximum depth of the sensor was controlled by the subjects from the onset of uncomfortable sensation. By pressing a special button, the participant stopped the immersion of the sensor head into soft tissue. The experiment was carried out on three series of measurements on the right and left hand.

Preliminary analysis of the results of the second part of the experiment.

From the plotted data we calculated Young's modulus *as the index of stiffness* using the formula $\mathbf{Y = average\ (F_{1\text{-}n}/\mu_{2\text{-}n})}$, where $F_{1\text{-}n}$ **-** the value of force registered from the first point of 0.05 mm of deflection to the final value of force, measured at maximum deflection in this experiment. For example, the force measured on the first point of deflection (0.05 mm of immersion) was 0.012N, on the second point of deflection (0.1 mm) was 0.025N, on the third point of deflection (0.15 mm) was 0.035 N, on the last point of deflection (10.5 mm- 210 points) was 14.9 N. Then, the result of Young's modulus, calculated for the first point of deflection was 0.012/0.05=0.24 N/mm, for the second point of deflection - 0.025/0.1 = 0.25, for the third point of deflection - 0.035/0.15 = 0.23, for the last point of deflection – 14.9/10.5 = 0.142. The average Young's modulus over the experiment is calculated as Y=(0.24+0.25+0.23……..+0.142)/210.

Statistical analysis of the results was performed by one factor ANOVA.

Correlations between the values of maximum voluntary muscle strength and muscle stiffness were computed using the Pearson's linear correlation coefficient. Because the Pearson mathematic technique based only on the linear relationship between the above parameters, we also calculated a more accurate point-biserial coefficient of nonlinear dependencies separately from the "weak" and "strong" subjects. Group of "strong" and "weak" subjects were allocated by the values of the average results of maximum force for each hand and standard deviation (also for each hand).

Results

Study of maximum isometric force of FDI showed that the vast majority of subjects demonstrated a greater force from their dominant hand. Also, six people (18 experiments out of 165) demonstrated higher strength from their muscle on the non-dominant side. This allowed us to stream the total number of right handed subjects into two groups: "typical" and "atypical" (Table 1). In both groups there was a significant difference in terms of average values of maximum voluntary force from the dominant and non-dominant hands.

Group of right-handers	Hand	Number of Experiments	Deflection мм	Young Modulus N/mm
«Typical» 49 participants	Non Dominant	147	10.92±2.27	0.2261± 0.0174
	Dominant	147	10.75±2.45	0. 2725± 0.01855
			P>0.05	P<0.001*
«Non Typical» 6 participants	Non Dominant	18	10.46±3.65	0.2693± 0.0225
	Dominant	18	10.35±3.27	0.2215 ± 0.024
			P>0.05	P< 0.01*

Table 1 Average values and standard deviations of voluntary maximum isometric force of muscle contractions and its distribution in the groups of subjects with values of Young Modulus

* - Statistical difference

We have received a high degree of Pearson linear correlation and a reasonably .high degree of point-bisserial (nonlinear) correlation between the groups of "strong" and "weak" right-handers. This was observed in the total group of right-handers as well as in the selected groups (Table 2).

Table 2. Correlation coefficients between the maximum isometric voluntary force and the level of stiffness to deformation.

Group of right-handers	Hand	Number of Experiments	Pearson Coefficient of correlation	Point-biserial Coefficient of correlation
«Total» 55 participants	Non Dominant	165	0.682	0.785
	Dominant	165	0.645	0.746
«Typical» 49	Non Dominant	147	0.628	0.824
	Dominant	147	0.612	0.839

participants				
«Non Typical» 6 participants	Non Dominant	18	0.701	0.788
	Dominant	18	0.666	0.811

Discussion.

The main purpose of our study was to explain the "Rule of 10%” on the basis of influence of the biomechanical properties of skeletal muscle tissue on development of muscular force. "10% Rule" is that when a pronounced right-handed participant sometimes (approximately 10% probability) demonstrated a greater force developed from the muscles of non-dominant hand [2,9,10,18]. Our experiments, performed using a model of a single muscle contraction has fully confirmed the validity of this rule, because 6 out of 55 subjects clearly demonstrated the predominance of maximum isometric force from their non-dominant hand.

Some researchers believe that maximum voluntary muscle force (especially grip force) has a mild level of lateralization [7, 10]. However, using this point we cannot explain the "Rule of 10%" because this suggestion implies lack of distinction between right and left hands in the development of maximum force, which contradicts our results (significant isolateral difference between forces in both groups).

Yielder and colleagues [18,19] have attempted to partly explain this rule by showing that the FDI on the non-dominant hand in some of their subjects had a greater angle of attachment to the metacarpal axis. This might give some biomechanical advantage to their FDI on the left hand in developing maximum isometric force. Some other researchers have previously pointed out that such differences in the generation of force by FDI also may be associated with varying degrees of involvement of its large and small heads, which contribute different forces during flexion and abduction [3]. Also the isolateral differences in maximum force may be due to a lower threshold of recruitment of motor units in both sides [4,5].

According to the classic approach the force of resistance elicited by a soft tissue strain unit is defined as a stiffness of this tissue [20]. In our experiment there is a strong relationship between stiffness of FDI and its maximum isometric force. This allows us to conclude that stiffness is an important biomechanical factor in the development of force. In the group of "Non typical right-handers," stiffness of FDI was higher in the left hand, and the FDI from their left hand developed greater maximum voluntary isometric force, despite the fact that all participants were pronounced right-handers according to the classical approach by Oldfield [15]. Electrophysiological studies of FDI and studies of its histo chemical characteristics showed that many left hand FDI muscles have a predominance of fast twitch fibers, whose diameters are substantially greater than slow twitch fibers [1, 6,16]. This means the possibility of a higher concentration of the coating endomysium of the muscle fibers of non dominant FDI muscles, which determines their stiffness [20]. Such an approach is also based on the principles of peripheral asymmetry used in modern science [8,19]

Conclusions:

1. Our study has confirmed the "Rule of 10%" for a single FDI muscle. This establishes grounds for a critical attitude to the use of maximum force measurement technique for testing handedness.
2. The level of developed muscle force is dependent on its stiffness, which makes it possible to predict the force generated behavior of a variety of contractile muscles.
3. The existence of "Rule of 10%" may be partly explained by greater stiffness in muscles of the non-dominant hand in 10% of right handed people. For more detailed findings related to the explanation of this rule it is necessary to pay attention to other biomechanical parameters (e.g. the degree and time of relaxation of the muscle after compression, the residual strain, etc.).

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