# HANDGRIP STRENGTH AND SELECTED ENDURANCE VARIABLES

**by**

**ROBERT STASZKIEWICZ[1], TADEUSZ RUCHLEWICZ[2], JAN SZOPA[3]**

The muscles of a dominant hand were investigated in 424 subjects (168 males and 256 females). The aim of this study was to evaluate the dependence between muscle strength and endurance during maximal voluntary contractions (MVC). Three types of isometric contractions were applied: 75, 50 and 25% of maximal strength (Fmax) and all experiments were performed until exhaustion. The relationship between contraction time and external load of muscle was calculated. The exponential function gives the best fitting of measured data. They were drawn a curves for men and women. It seems the experiment with 50% of maximal handgrip force gives the best information about muscle endurance than other abilities.

**Key words**: muscular strength – dominant hand – endurance

## *Introduction*

Endurance may be commonly understood as resistance to fatigue. It is most often defined as the ability to perform prolonged muscular work at pre-determined intensity without external signs of fatigue. This definition suggests that endurance may be evaluated by endurance time. This is why the term "endurance time" is often used for determining the level of endurance (Seals 1993, Ng et al. 1994, West et al. 1995). In accordance to this definition endurance may be evaluated at different values of power, under aerobic and anaerobic conditions. The experimental data also exists for tests conducted under isometric conditions (Chatterjee and Chowdhuri 1991, Chan et al. 2000,

[1, 2)] Drs, University School of Physical Education, Cracow, Al. Jana Pawla II 78, Poland first author e-mail wastaszk@cyf-kr.edu.pl
[3)] Prof. dr., University School of Physical Education, Katowice, Mikolowska 72, Poland

Louhevaara et al. 2000), at maximal (Backman et al. 1995, Wit et al. 1999) or submaximal level of strength (Cotzias and Marshall 1993, Seals 1993). Previously conducted research (Dworak and Haremza 1985, Ruchlewicz and Staszkiewicz 1998) indicates that endurance time decreases with the increase of strength of isometric contraction.

The main aim of this work is the evaluation of this relationship between muscular strength and endurance in tests performed under isometric conditions at 25%, 50%, 75% of maximal strength ($F_{max)}$. The authors attempt to explain unequivocal results presented by other researchers related to the influence of maximal muscular strength on variables determining prolonged isometric contraction.

## *Material and methods*

The research was conducted in a group of 424 students of Academy of Physical Education between the age of 20-23 years (169 males and 256 females). Among the tested subjects 21 males and 20 females were left-handed. The average values of body mass and height were 81±0,06 kg and 1,67±0,06 m for males and 76,1±9,11 kg and 58,1±6,24 kg for females.

The scope of the research included two different aspects of functional muscular characteristics of the dominant hand:

a) strength variables of muscles responsible for hand-grip,
b) endurance variables of hand-grip.

The testing protocol included four tests performed in established sequence with the one week rest period. The strength and endurance tests were carried out under isometric conditions with the use of measuring system consisting of force transducer (type Hottinger U9B/2kN), modular amplifier (type M-100), AD/DA card (14 BIT) and PC computer.

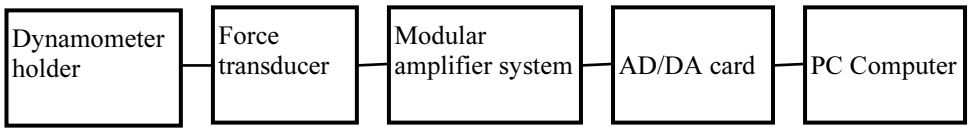


Fig. 1. Block diagram of measuring system

The evaluation were conducted with a hand dynamometer with regulated force points, which allow for the consideration of varying hand dimensions. The distance between resistance points was set in positions which allow to press with middle phalanx. The research subjects performed tests on a three plane regulated chair with the forearm on the parallel to the ground suspension with adjustable height what allowed for evaluation of maximal hand-grip strength of the dominant hand – $\mathbf{F_{max}}$ [N].

The measures of muscular endurance were also performed. This evaluation included the maintenance of hand-grip at the set force of 25 ($\mathbf{t_{25\%Fmax}}$), 50 ($\mathbf{t_{50\%Fmax}}$) and 75% of $F_{max}$ ($\mathbf{t_{75\%Fmax}}$). The visual feedback of produced force was presented on computer screen to tested subject during the entire performance.

With the use of smallest squares estimation method the function describing the relationship between the endurance time and its level was formulated t=f(F).

Statistical analysis included basic descriptive characteristics ($\overline{x}$, SD, min, max), intergroup paired t-Student test and Pearson linear correlation.

*Results*

The characteristics of hand-grip strength presented in table 1 indicate 1.7 higher values in males in comparison to females.

Table 1. Maximal handgrip strength $\mathbf{F_{max}}$ [N] in male (**M**) and female (**F**); * - significant difference between both sexes $\alpha$<0,001.

| | $\overline{x}$ **±SD** [N] | **min** [N] | **max** [N] |
|---|---|---|---|
| **M** | 679,4±102,4 * | 469,7 | 1035,0 |
| **F** | 393,1±60,2 | 227,7 | 564,2 |

The results of dynamometer endurance time reached in conditions of 25, 50 and 75% of Fmax are presented in table 2.

Table 2. Endurance time: 75, 50 and 25% Fmax (**M** – male, **F** – female, * - significance gender differences at p<0,001).

| | $t_{75\%Fmax}$ [s] | | | $t_{50\%Fmax}$ [s] | | | $t_{25\%Fmax}$ [s] | | |
|---|---|---|---|---|---|---|---|---|---|
| | $\bar{x}$±SD | min | max | $\bar{x}$±SD | min | max | $\bar{x}$±SD | min | max |
| M | 36,7±10,1 * | 20,0 | 71,3 | 79,2±24,4 * | 34,5 | 183,9 | 362,1±125,3 | 139,0 | 787,0 |
| F | 44,8±18,9 | 9,3 | 102,0 | 98,7±37,3 | 28,1 | 273,6 | 363,6±134,2 | 90,0 | 789,0 |

The average $t_{75\%Fmax}$ did not exceed 1 min. in the research groups and was 8 s longer in the group of females what was statistically significant. In case of females $t_{50\%Fmax}$ exceeded 90 s and this values were 25% longer in case of females and this difference was statistically significant. The $t_{25\%Fmax}$ did not differ significantly between males and females and the values slightly exceeded 6 min. for both groups.

The data analysis presented in table 2 indicates that decrease in produced hand-grip force was accompanied with increase of endurance time. The comparison of average times of the three hand-grip endurance tests is presented in fig. 2.

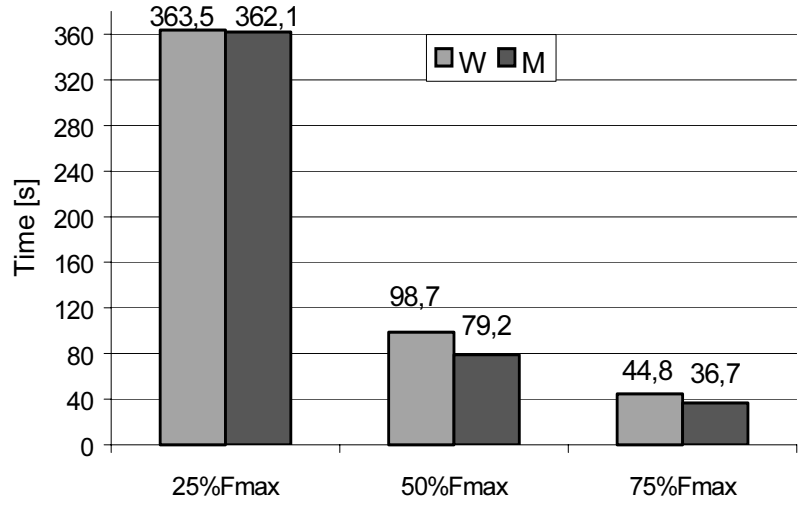


Fig. 2. Mean values of endurance time (75, 50 and 25% $F_{max}$) in men (M) and women (W).

During function computation describing the relationship between endurance time and the value of force it appeared that this phenomenon is best described by exponential function in case of individual subjects (fig. 3) as well as for whole groups of males (fig. 4) and females (fig 5).

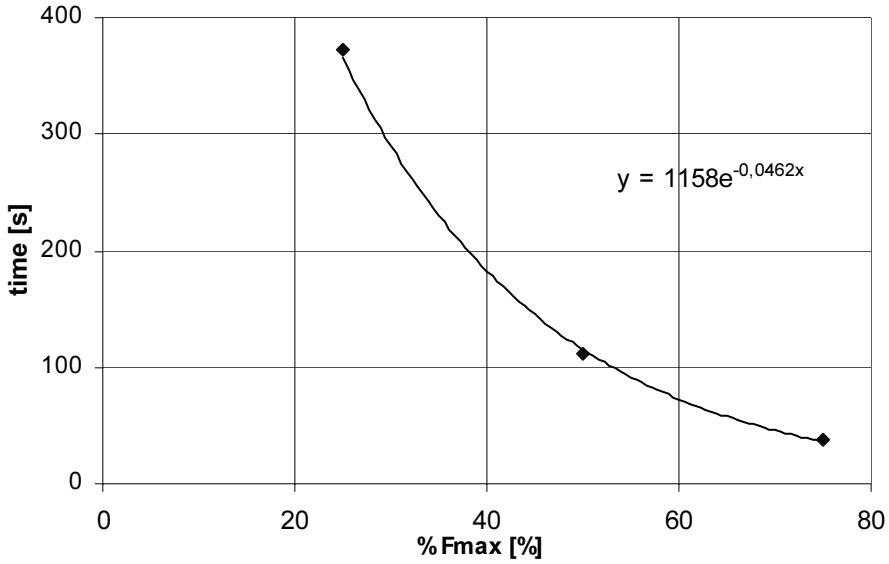


Fig. 3. Relationship between endurance time and the value of handgrip strength for one subject

Applying the most often used approximation function – smallest squares estimation method a function which was expressed for males by an equation $y=955,2\ e^{-0,045x}$, and for females $y=923,5\ e^{-0,042x}$.

In order to verify the best fitting of function for the acquired data the coefficient of determination (R-square) was calculated for both groups. The value of this coefficient varies from 0 to 1 and the last value indicates that independent variables included in the model completely determine the dependent variables.

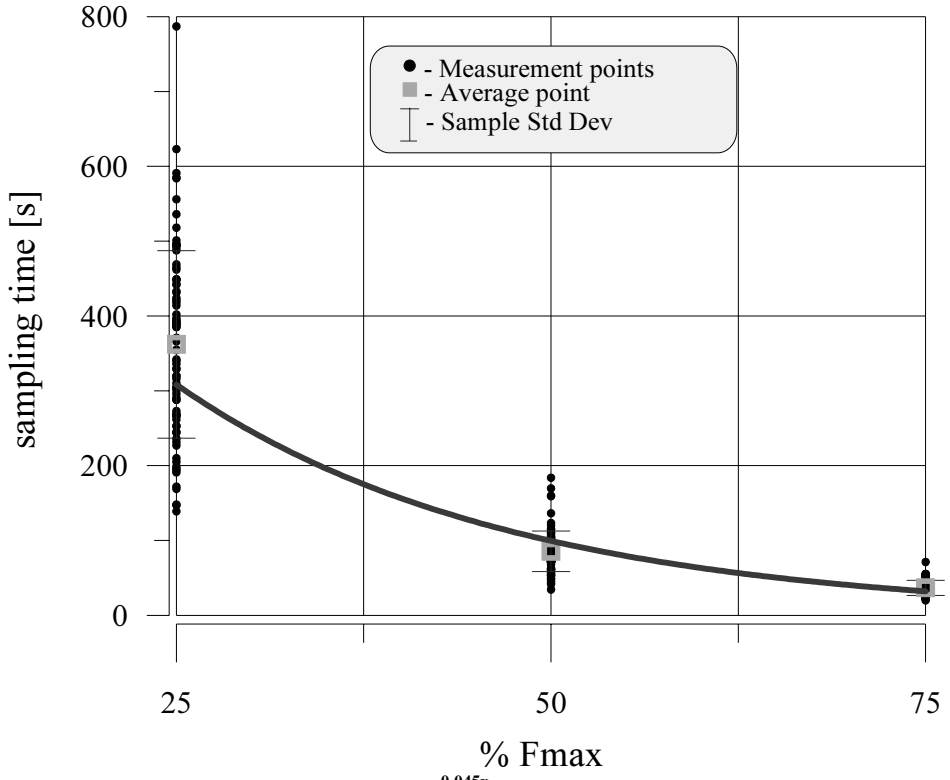


Fig. 4. Exponential function (**y=955,2 e$^{-0,045x}$**) describing endurance time and value of handgrip strength in men (n=168).

The value of coefficient of determination (R-square) calculated for the males equaled 0.88 what shows that 88% of time variance is determined by the regression line and only 12% remains as residual. High quality of curve identification are additionally confirmed by regression sum of squares = 212,28 and residual sum of squares =29,34. Figure 5 presents the exponential function approximated to the results of endurance in group of females. Quality of identification of this function is described by the value of determination coefficient equaled 0.81; regression sum of squares = 182.25 and residual sum of squares =43.26.

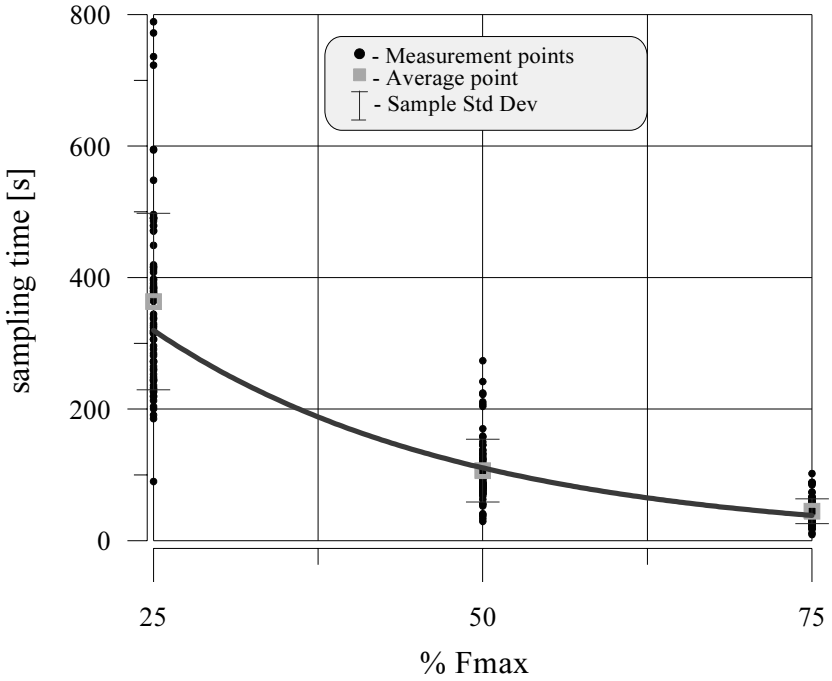


Fig. 5. Exponential function (**$y=923,5\ e^{-0,042x}$**) describing endurance time and value of handgrip strength in women (n=256).

The functions qualitatively describing the relationship between the time of isometric contraction and the value of force are similar for males and females. The measures of function approximation are at the same level for both sexes. Table 3 presents the values of the Pearson linear correlation coefficients between the analyzed variables in groups of females and males.

Table 3. The values of correlation coefficients (r - Pearson) between measured variables in groups men and women

| **W (n=256)** | | | | **M (n=168)** | | | |
|---|---|---|---|---|---|---|---|
| | **$F_{max}$** | **$t_{25\%Fmax}$** | **$t_{50\%Fmax}$** | | **$F_{max}$** | **$t_{25\%Fmax}$** | **$t_{50\%Fmax}$** |
| **$t_{25\%Fmax}$** | **-0,47*** | | | **$t_{25\%Fmax}$** | **-0,22**** | | |
| **$t_{50\%Fmax}$** | **-0,29*** | **0,67*** | | **$t_{50\%Fmax}$** | **-0,44*** | **0,49*** | |
| **$t_{75\%Fmax}$** | **-0,40*** | **0,60*** | **0,63*** | **$t_{75\%Fmax}$** | **-0,26**** | **0,28**** | **0,55*** |

The correlation between hand-grip strength ($F_{max}$) and endurance time ($t_{25\%Fmax}$, $t_{50\%Fmax}$, $t_{75\%Fmax}$) are negative and reached values from - 0,22 do - 0,47. The correlation coefficients between times of the isometric contraction at different levels of force ($t_{25\%Fmax}$, $t_{50\%Fmax}$, $t_{75\%Fmax}$) indicate significant positive relationships between these variables in the group of females (**r** from 0,6 to 0,67). Described above relationships are weaker in males and reached values from 0,28 to 0,55. The weakest relationship in case of both sexes was observed between endurance times of the two distant values of force ($t_{25\%Fmax}$, $t_{75\%Fmax}$), however in case of females this correlation is much higher (r=0.60) than in males (r=0.28).

## *Discussion*

In evaluation of strength possibilities of the hand the torque developed by the muscles is rarely measured while the dynamic value presented is called hand-grip strength. Its value is equal to the squeezing force which is dependent on the type of grip (Nadolski 1977). The measurement is usually conducted under static conditions since the value of force obtained under such conditions is greater than during isokinetic measurements (LaStayo and Hartzel 1999). The result of measurement is sometimes incorrectly interpreted as the strength of finger flexors (Kasperczyk 1990).

The hand position proposed in this research can be included to the so called power grasp (Cukotsky and Howe 1990, Cytowicz-Karpiłowska et al. 1996). It allows for the development of great force while maintaining unchanged biokinematic pairs configuration (stability of mechanical conditions of the contraction). The choice of the middle phalanx as the parts of the hands where force is applied to one of the sides of the dynamometer considered the data of Hazelton et al. (1975) suggesting that in such configuration greatest values of hand-grip strengths will be produced. Recent reports of Blackwell et al. (1999) comparing grip size with strength additionally verified the choice of research protocol.

The obtained hand-grip strength ($F_{max}$) is greater in males what has been often confirmed by other authors (Misner et al. 1990, Rice et al. 1998, Ditor and Hicks 1999). This data confirms sexual dimorphism exemplified in strength

possibilities, a commonly known and often described phenomenon (Jaszczuk et al. 1987, Ruchlewicz et al. 1997).

During the evaluation of muscular endurance where isometric contraction was maintained at forces corresponding to 25, 50 and 75% of Fmax it was determined that lengthening of the endurance time was accompanied by a decrease in the produced force. This observation was expected and presented in literature by many authors (Dworak and Haremza 1985, Seals 1993, Ng et al. 1994).

The results indicate an existence of sex difference in relation to endurance time at predetermined strength values yet they diminish with the decrease in the value of the applied force (tab. 2). Similar significant differences favoring females in endurance time were observed by Misner et al. (1990), while a tendency for equalization of results between sexes (when force of contraction decreases) was registered by West et al. (1995).

Hand-grip strength ($\mathbf{F_{max}}$) and the time of isometric contraction ($\mathbf{t_{25\%Fmax}}$, $\mathbf{t_{50\%Fmax}}$, $\mathbf{t_{75\%Fmax}}$) are significantly related and this these relationship is negative. The relationships between mentioned variables were similar in case of both sexes. The above mentioned relationships between time and force have been confirmed by Morecki et al. (1990) and Kasperczyk (1990).

In light of available knowledge and own data one can assume that the time of the test (maintenance of isometric contraction) accepted as a measure of endurance is dependent on the absolute value of muscular strength. It influences the level of blood flow transporting oxygen and energetic substrates to the working muscles. A contracted muscle creates pressure inside it which impairs arterial and vascular circulation. The proportions of intramuscular and arterial pressures influence the transport of substrates and both of this values can vary individually.

The analysis of obtained data allows for considerations if the results of endurance tests under conditions of isometric contraction may be compared individually. As long as the critical value of muscular tension below which the light of arteries and veins are sufficiently open is undetermined the diagnostic value of such tests is questionable.

As mentioned previously the time of the maintenance of isometric contraction at a predetermined force value is a function of that force t = f

($\%F_{max}$). This relationship is not linear and this phenomenon is not questioned by researchers yet particular reports differ in qualitative aspects. Kobryn et al. (1978) proposed a parabolic description of relationships between time and force what can be true yet not for the whole range of variance. The wrong approximation to the obtained data by Dworak and Haremza (1985) was also observed. In this case there are doubts in relation to the extrapolation of the function $t = f(\%M_z)$ to the value of $25\%M_{max}$.

The proposed exponential function as that best describing the character of changes was confirmed not only through mathematical analysis but additionally by conclusions from research of other authors. Kahna et al. (1997) presented data which states that the time of an isometric contraction equaled to 10 % of Fmax may exceed 1 hour. These authors indicate that this time may be significantly longer yet evaluations are difficult under such conditions due to motivation. The cited authors determined the value of isometric strength of contraction under which there is little fatigue and called it the critical force of muscle. This value was estimated as 15 to 20% of maximal possibilities.

The properness of the applied method of approximation may be confirmed by the curve presenting changes of static muscular endurance and the value of force presented by Rohmert (1960). The asymptosis described by this author related to the time-force relationship reaches a value approximately 15% of Fmax and is in accordance with data presented by Kahna et al. (1997).

Exponential curve obtained as a result of endurance research shows, that the tests with the small loads last too long and do not describe muscular endurance but rather mental resistance to fatigue in long-lasting tasks with low intensity. Tests with greater loads are accompanied by fast depletion of energetic substrates which is the consequence of blocking of internal muscular transport system. Thus it seems that the muscular endurance tests with the application of 50% of Fmax is most appropriate. On the other side the determination of negative relationships between maximal muscular strength and the time of the tests as well as significantly longer times obtained in females (significantly weaker than males) indicate that evaluation of endurance under isometric contraction give questionable results. The results of these tests are affected by many external factors and their interpretation causes significant doubts (Wolański and Pařizková 1976, Kasperczyk 1990).

*Conclusions*

The obtained data and its analysis allow to formulate following conclusions:

1. The differences between females and males in the time of the isometric contractions performed under 25, 50 and 75% of maximal strength diminish with the decrease of produced force.
2. The relationship between the time of the isometric contraction and the value of force expressed as a fraction of maximal value t = f ($\%F_{max}$) is best described by the exponential function.
3. The static test with the load set at 50% Fmax is the most valid description of endurance in isometric submaximal contractions.

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