Original Article

Study and analysis of armwrestlers' forearm muscles' strength

PODRIGALO L.V.[1], IERMAKOV S.S.[2], NOSKO M.O.[3], GALASHKO M.N.[1], GALASHKO N.I.[1]
[1]Kharkov State Academy of Physical Culture, UKRAINE
[2]Kazimierz Wielki University in Bydgoszcz, POLAND
[3]Chernigiv National T.G. Shevchenko Pedagogical University, UKRAINE

Abstract:
Positive tendencies of arm-wrestling's expansion condition demand in its scientific study and determination of sportsmen's success factors. Such factors include strength of sportsman's forearm muscles' strength.
The purpose of the research is comparative analysis of forearm movements' power characteristics of different qualification sportsmen and students, who do not practice arm-wrestling.
Material and methods: in experiment 33 students of physical culture academy participated. The students were divided in two groups: experimental group – armwrestlers, (n=16, age 21.94±1.18 years), the second (control) group) (n=17, age 19.94±0.31 years) – students, who do not practice armwrestling. Depending on level of sportsmanship experimental group was divided into two sub-groups: experienced sportsmen (n=5) and beginners (n=11). We used set of tests. In the tests we registered strength of flexing, extension, moving aside, forearm's pronation and supination by value of maximal weight in these movements.
Results: higher strength of sportsmen, in comparison with control group, by all tested parameters has been confirmed (p<0,05). Especially greater sportsmen's strength is expressed with flexing of forearm. It reflects better physical fitness and illustrates specialized training in this kind of sports. Indices of strength's relation to mass improve visibility and permit to standardize the data for analysis and prognosis. Value of experienced sportsmen's flexing indices was more than 100%. It proves again importance of this movement for success in armwrestling. Analysis of correlation matrixes confirmed greater stability of sportsmen's condition. Reduction of functional tension happens at the account of 1.2 – 2.0 times increase of specific gravity of significant and confident correlations, as well as 2.48 times increase of synchronization indicators and 2 times increase of mean correlation coefficient.
Conclusions: level of strength in flexing, extension, rotation and moving forearm aside is rather important for success in armwrestling. Usage of indices of strength-body mass relation is a promising way of selection and prognostication in armwrestling.
Key words: arm-wrestling, strength, muscles, forearm, correlations.

Introduction
        Strength is one of main physical features, determining success in different kinds of sports. For example Baláš, Pecha, Martin and Cochrane (2011) researches muscular strength, endurance and body composition of sportsmen-mountaineers. The authors found that arms' strength and endurance are predictors of sportsmanship. The received results permitted to make conclusion that there is interconnection between these components. These results were confirmed with simulation by structural equations. Analogous results were obtained in researching of elite sportsmen's morphological characteristics in climbing for speed and mountaineering (Ryepko, 2013). Among other similar researches we can mark out the following works: analysis of influence of 10-weeks' power training program on body composition, muscular strength and endurance (Chromiak et al., 2004); dependence of body mass on sportsmen's physical fitness and body composition (Ko & You, 2015); research of hand's seize strength and forearm's maximal force (Nicolay & Walker, 2005); manifestation of maximal strength and muscular parameters during long term bicycle ride (Hausswirth et al., 2010). Results of the listed researches witness about interaction between power characteristics and body composition and their influence on sportsmen's physical fitness. The authors showed that body mass index shall be regarded as an important element for studying of movements' characteristics. The character of training loads on upper limbs is also of the same importance (Kamaev & Bezkorovainyi, 2013).
        Significance of arm's strength training as factors of success was confirmed in swimming (Dummer, et al., 1985), in golf (Sung, Park, Kim, Kwon, & Lim, 2014), Nordic Walking (Song, Yoo, Choi, & Kim, 2013). It was detected that maximal power training improves efficiency of muscles' work and their endurance (Kemi et al., 2010; Hassanlouei, Falla, Arendt-Nielsen, & Kersting, 2014).

At present popularity of power kinds of sports has been growing. It is conditioned by expansion of fitness, the part of which they are as well as by attractiveness and accessibility of them for wide strata of population and youth. Armwrestling takes significant place in this group owing to its power orientation and character of duel. At present time armwrestling has not had sufficient scientific basis, required for its development. Most of publications are of practical character, based on empiric results of sportsmen's training, and are written by coaches.

At the same time demand in scientific study of this kind of sports has been proved by results of complex researches of armwrestlers of different qualification. Application of physiological, bio-chemical, bio-physical, hygienic and other methodic permitted to substantiate and work out system of selection and control over functional state (Podrigalo, Istomin, & Galashko, 2010). Analysis of armwrestling with the help of conceptions of ergonomics permitted to find out that in sportsmen's training working out of forearm's muscles shall take central place (Podrigalo, Galashko, & Galashko, 2012). But its assessment is carried out exclusively by results of hand dynamometry. The received by us results permitted to recommend this methodic as screening when selecting promising sportsmen and in current control of their functional state (Podrigalo, Galashko, Galashko, Prusik, & Cieślicka, 2014). The used by the authors test is mainly oriented on assessment of strength of seize. Strength of movements in radiocarpal joint is characterized by it to less extent. At the same time motor amplitude in this joint is an important factor of prognostication in armwrestling (Podrigalo, Galashko, & Galashko, 2013). This fact permits to assume that strength of movements in this joint is rather important for success in armwrestling. For example, results of Nichols, Bednar, Havey and Murray, (2015); Yung and Wells (2013) witness that the moment of wrist muscles in flexing-extension and radial-elbow moving aside is determined by balance between agonist and antagonist muscles.

In sport movements athlete's arm can be regarded as open or closed kinematic chain (Iermakov, Adashevskiy, & Sivolap, 2010; Adashevskiy, Dylewski, & Iermakov, 2011; Nosko, Arkhypov, 2011; Potop, Grad, & Boloban, 2013; Yung et al., 2013; Adashevskiy et al., 2014). Study of armwrestling duel from position of biomechanics and ergonomics defined armwrestler's arm as closed kinematic chain. Character of movements in this chain differs depending on action: defensive or attacking (Podrigalo et al., 2011, 2012). In attack it is a combination of several movements: flexing, moving aside and rotation. In defense – it is extension, moving aside, rotation. I.e. for duel in armwrestling combining of seize and different movements in different planes are characteristic. Analysis of such complex movements was conducted by Smets, Potvin and Keir (2009). Its results showed the presence of interconnections between strength of seize, angle joint's flexing and length of levers (Yamazaki, Suzuki, Ohkuwa, & Itoh, 2003; Bergmann et al., 2011; Crisco et al., 2015).

Thus, study of strength of forearm's muscles can be used for analysis of morphological-functional state of sportsmen and will permit to predict sportsmen's success.

So, **the purpose of this work** was study and comparative analysis of forearm's strength of different qualification armwrestlers and students' who do not practice this kind of sports.

Material and methods
Participants

In experiment 33 students of physical culture academy participated (Kharkov). The students were divided in two groups: experimental group – arm-wrestlers, (n=16, age 21.94±1.18 years), the second (control) group (n=17, age 19.94±0.31 years) – students, who do not practice arm-wrestling. Age differences are not confident (p>0.05). Depending on level of sportsmanship experimental group was divided into two sub-groups: 1a -experienced sportsmen (n=5, mean age 27.20±2.29 years) and 1b - beginners (n=1, mean age 19.55±051). Age differences of sub groups are confident (p<0.05), that is conditioned by different period of trainings.

The study Protocol was approved by Committee on Ethic of Kharkov State Academy of Physical Culture. Besides, all participants of experiment were informed about all details of the research and signed the document of informed agreement.

The structure of the research implied measurement of body mass and muscles' strength of forearms in flexing, extension, moving aside, supination and pronation by maximal value of load, which with fulfillment of these movements is possible. Flexing and extension strength was registered simultaneously for both arms, holding weights. When measuring flexing both arms were placed on edge of bench with hands hanging horizontally. The tested made maximal movement by both hands with weights upward. When measuring extension strength, the tested was in sitting position with both forearms on knees. He made maximal movement upward from horizontal position (without loosing contact of forearms). Moving aside, pronation and supination were assessed separately for right and left arms. In these tests we used belt, on which weight was fixed. Pronation strength was determined form position hand – upward with elbow's rest on abdomen. Hand rotated in position "thumb vertically" with simultaneous flexing of hand to forearm. Supination strength: from initial position "rest on table for armwrestling" hand hangs over the table. Hand rotates by 90 degrees. Strength of moving aside: from initial position "elbow's rest on abdomen"; belt goes between 2-5 fingers; hand is in vertical position, maximally dropped down. Then hand rises upward to its physiological position. All tests were conducted three times with registration of maximal result.

Statistical analysis of the received data was conducted with the help of licensed electronic tables Excel. We determined indicators of descriptive statistic (mean arithmetic value, standard deviation and error of mean value). Confidence of differences of mean values was assessed by Student's criterion with differences being considered confident at (p<0.05). For determination of correlations between indicators we calculated correlation coefficients by Pirson and constructed correlation matrixes (Antomonov, 2006). Comparative analysis of correlation matrixes was conducted with usage of the following indicators: specific gravity of significant and confident correlations; indicator of labilization/synchronization (ILS); value of mean correlation coefficient (MCC). The latter two indicators were determined by special formulas, given in work by Zosimov (2000):

$$ILS = [n/N(N-1)] \times 100\% \tag{1},$$

where n – sum of all significant correlations, created by every parameter of correlation structure; N – total quantity of structure's parameters.

$$MCC = \Sigma rj/n \tag{2},$$

where Σrj – sum of values of all confident correlation coefficients of the structure;
n – quantity of significant correlations.

Results

The received results are given in table 1. Study of body mass was conducted in connection with the fact that in armwrestling wrestlers are divided by weight classes. As the received data witness participants of experiment do not differ significantly by body mass (p<0,05).

Table 1. Power of main forearm's movements in experimental and control groups

Indicator, kg	1 group	1a sub group	1b sub group	2 group
Body mass	79.94±2.65	75.40±4.88	74.73±3.31	70.05±2.16
Flexing	77.28±3.33[2]	84.50±5.94[2]	74.00±3.79[2]	54.62±1.87
Extension	23.19±1.10[2]	23.80±2.24[2]	22.91±1.31[2]	15.91±0.38
Pronation from the right	27.38±1.86[2]	29.80±3.89[1]	26.27±2.10[2]	17.91±0.53
Pronation from the left	25.50±1.80[2]	27.60±3.57[1]	24.55±2.11[2]	17.50±0.52
Supination from the right	21.63±1.68[2]	22.50±3.11[1]	21.23±1.72[2]	15.53±0.41
Supination from the left	20.25±1.05[2]	19.80±1.83[1]	20.45±1.33[2]	15.56±0.43
Moving aside right arm	15.00±0.85[2]	16.40±1.83[1]	14.36±0.92[1]	11.71±0.30
Moving aside left arm	14.03±0.76[2]	15.10±1.69[1]	13.55±0.82[1]	11.44±0.34

Notes. 1 – differences from 2nd group are confident (p<0.05), 2 – differences from 2nd group are confident (p<0.01).

The data of table 1 definitely illustrate greater strength of sportsmen in comparison with control group. By all tested movements we confirmed substantial (p<0.01) increment of indicators in 1st group. The detected regularity is observed also in comparative analysis of sub groups, which differ by level of sportsmanship. Experienced sportsmen have significantly higher indicators of forearm strength by all tests. At the same time results of subgroups 1a and 1b did not differ significantly by any of tested indicator.

It was interesting to assess hierarchy of the registered indicators. As far as flexing and extension power was assessed for both arms simultaneously these results can be comparable with other after dividing them into two parts. Thus, in 1st group strength of forearm muscles reduces in the following sequence: flexing, pronation from the right and from the left, supination from the right and from the left, moving aside right arm and left arm with extension at the end. In control group the order is practically similar with following exclusion: supination from the left is higher than from the right.

In group of sportsmen and in control group there were absent significant differences between indicators of right and left arms (p<0.05). It witnesses about absence of asymmetry in physical condition of participants of the experiment.

When assessing strength it is habitual to use indices, representing relation of results to body mass. Their application permits to certain extent to standardize the available data. Earlier we proved that application of indices in armwrestling was rather promising. Besides, we marked out the most informative indices, suitable for prognostication of success (Podrigalo et al., 2010). In this very case we calculated indices, representing relation of sportsman's strength to body mass in percents. The received results are given in table 2.

Table 2. Relative strength of forearm's muscles in experimental and control groups

Index, %	1 group	1a sub group	1b sub group	2 group
Flexing	103.21 ± 3.02^2	112.46 ± 6.40^2	99.00 ± 2.62^2	78.14 ± 1.78
Extension	30.81 ± 0.67^2	31.33 ± 0.98^2	30.57 ± 0.89^2	22.86 ± 0.48
Pronation from the right	36.23 ± 2.00^2	39.06 ± 4.02^2	34.95 ± 2.30^2	25.67 ± 0.54
Pronation from the left	33.78 ± 2.00^2	36.17 ± 3.50^2	32.69 ± 2.48^2	25.12 ± 0.62
Supination from the right	28.85 ± 1.78^2	29.47 ± 2.97^1	28.57 ± 2.30^1	22.35 ± 0.63
Supination from the left	27.04 ± 1.16^2	26.22 ± 1.83	27.42 ± 1.51^2	22.41 ± 0.68
Moving aside right arm	19.85 ± 0.66^2	21.51 ± 1.26^2	19.09 ± 0.69^1	16.88 ± 0.53
Moving aside left arm	18.65 ± 0.70^1	19.83 ± 1.44^1	18.11 ± 0.77	16.51 ± 0.59

Notes. 1 – differences from 2nd group are confident ($p<0.05$), 2 – differences from 2nd group are confident ($p<0.01$).

We established that indicators of relative strength rather visually illustrate increment of power in sportsmen's main movements, comparing with control group. Substantial differences were absent only with comparison of supination by left arm in sub group 1a and moving aside by left arm of beginners in comparison with control group (see table 2).

It is also interesting that in flexing relative strength in group 1 and sub group 1a was more than 100%. I.e. it was more than body mass. In our opinion it proves one more the conclusions about importance of this movement in armwrestling and permits to recommend this index for selection and prognostication in this kind of sports.

Our researches confirmed adequacy of correlation matrixes' method for analysis of armwrestlers' condition (Podrigalo et al., 2013). Just it conditioned its application in this very case. Main indicators of correlation structures witness about increasing of movements' characteristics in sportsmen's group in comparison with control group (see table 3).

Table 3. Indicators of correlation matrixes of forearm's strength in experimental and control groups

Group	Specific gravity of significant correlations (%)	Specific gravity of confident correlations (%)	Indicator of labilization/synchronization	Mean correlation coefficient
1	78.68 ± 3.51^1	64.71 ± 4.10^1	71.92	0.68
2	64.71 ± 4.10	32.35 ± 4.01	28.98	0.34

Notes. 1 – differences from 2nd group are confident ($p<0.05$).

Discussion

Results, given in table 1, permit to make conclusion that strength sportsmen's forearm muscles is greater than in control group. It reflects their higher physical fitness and illustrates specialized training in this kind of sports. Absence of substantial differences in sub groups 1a and 1b shall be assessed as one more factor, confirming specificities of arm muscles' training. Maximal value of flexing force illustrates importance of this movement in armwrestling, orients training process on improvement of this movement, on increasing of its results. The received data about maximal strength of muscles-extensors coincide with results of Amell, Kumar, Narayan and Gil Coury (2000); Halperin, Aboodarda and Behm (2014); Pinter, Bobbert, van Soest and Smeets (2010).

Analysis of indicators' hierarchy witnesses about same orientation of wrist strength development of sportsmen and not sportsmen. In this case we observed significant differences in level of strength. Besides, the detected regularities reflect degree of muscles' participation in fulfilled movements. They can be assessed as indirect evidence of importance of some movements in armwrestling. In our opinion low level of extension strength implies additional working out of these muscles. This assumption is conditioned by analysis of armwrestling's ergonomic and tactic peculiarities, which have already been mentioned above. Unbending of wrist takes place in certain defensive movement, when stronger opponent unbend the wrist of his adversary. I.e. the detected lower strength of extensors shows that defensive movement is obviously losing. At the same time, increasing of muscles-extensors' strength permits to raise probability of victory.

Results, presented in table 2, confirm one more the made earlier conclusions. Besides, they are an argument in favor of analysis of not absolute but relative values of strength. The calculated indices are more obvious; they can be standardized and used for prognosis and control of functional state. Their dynamic permits to assess training's efficiency.

Analysis of data in table 3 permits to affirm that in group 1 condition of sportsmen is more optimal, comparing with group 2. Substantial prevailing of significant and confident correlations in group 1 ($p<0.05$) characterizes higher stability of system. It is also confirmed by the fact that indicator of synchronization in group 1 is 2 times higher in comparison with control group. This fact illustrates weakening of functional tension. Mean correlation of system in both groups belongs to interval of strong correlation. However, in control group this criterion is practically at the lowers border, while in experimental group it is on the

----

highest border of the interval. Correlation value in group 1 is 2 times higher and it permits to regard its contribution in system as more significant. I.e. analysis of correlation matrixes permits to assess functional state of sportsmen as stable, which is characterized by sufficient quantity of correlations with minimal unbalancing. Thus, analysis of correlation matrixes proves that sportsmen's functional tension is weaker than in control group.

The received results are important for prognosis of success in armwrestling. They confirm relevance of specialized tests for determination of sportsmen's physical fitness. There were offered rather sufficient quantity of tests, ensuring assessment of strength, power endurance of sportsmen, determination of the mentioned features' dependence on fulfilled movements (Bäcklund, & Nordgren, 1968; Chuang, You, Cai, & Chen, 1997; Dummer, Clarke, Vaccaro, Vander Velden, Goldfarb, & Sockler, 1985; Fujiwara, Toyama, & Kunita, 2003; Potop, Timnea, Mihaiu, Manole, 2014; Potop, & Cretu, 2015). With testing elite sportsmen's strength it is recommended to use determination of maximal weight, which a sportsman can lift one time, considering initial position and amplitude of the fulfilled movement. Romanenko (2005) offers battery of special tests for determination of special power endurance of wrist muscles-flexors. However, in armwrestling it is explosive power that is very important; i.e. ability to produce maximal force in minimal time. Besides, in duel not only flexing but also other movements can be realized.

Amell et al. (2000) registered influence of axial torso rotation and arm's position on driving force. There was found increase of muscular activity and reduction of strength in process of upper limb's flexing. Depending on position of upper limbs the most active were biceps and flexing muscles. Presence of high correlation between muscular activity and strength was confirmed. Werlauff and Fynbo (2014) conducted comparative analysis of different tests for assessment of arms' muscles strength. The authors detected that their information content differs depending on the tasks of tests and required correction. Analysis of armwrestling's ergonomic aspects (Podrigalo et al., 2012) permitted to mark out main arm's movements, realized in duel. They became the basis of tests, used in the present research.

Thus, the received results deepen available information about peculiarities of armwrestlers' morphological functional condition, about significance of forearm's muscles for prognosis of success. The applied methods of data processing and analysis permit to more accurately differentiate condition of sportsmen of different sportsmanship level.

Conclusions:

With the help of battery tests on determination of forearm's muscles strength we confirmed its increasing in sportsmen in comparison with persons, who do not practice sports. At the same time sportsmen of different sportsmanship level do not have noticeable differences in strength. It reflects specialized character of training in this kind of sports. Level of strength in flexing, extension, rotation and moving aside of forearm is rather important for success in armwrestling. The most expressed were differences in flexing that illustrates significance exactly of this movement in armwrestling. Application of indices, determining correlation of strength and body mass is rather promising for selection and prognosis in this kind of sports. Method of correlation matrixes confirmed that sportsmen's condition is more stable and their functional tension is lower than in control group.

References
Adashevskiy, V.M., Dylewski, Michal, Iermakov, S.S. (2011). Biomechanical aspects of technical-tactic actions in Judo. *Pedagogics, psychology, medical-biological problems of physical training and sports, 3,*3-7.
Adashevskiy, V.M., Dylewski, Michal, Iermakov, S.S. (2011). Simulation and determination of main rational biomechanical characteristics in javelin throw. *Physical education of students, 2,*3-7.
Adashevskiy, V.M., Iermakov, S.S., Logvinenko, Y.I., Cieślicka, Mirosława, Stankiewicz, Błażej, & Pilewska, Wiesława. (2014). Individual athletes' biomechanical features of interaction with objects in art gymnastics. *Pedagogics, psychology, medical-biological problems of physical training and sports, 6,*3-10. http://doi.org/10.6084/m9.figshare.1004089
Amell, T.K., Kumar, S., Narayan, Y., & Gil Coury, H.C. (2000). Effect of trunk rotation and arm position on gross upper extremity adduction strength and muscular activity. *Ergonomics, 43(4),*512–527. http://doi.org/10.1080/001401300184387
Antomonov, M.Iu. (2006). *Processing and analysis of biomedical data*, Kiev.
Bäcklund, L., & Nordgren, L. (1968). A New Method for Testing Isometric Muscle Strength under Standardized Conditions. *Scandinavian Journal of Clinical and Laboratory Investigation*, *21(1),*33–41. http://doi.org/10.3109/00365516809076974
Baláš, J., Pecha, O., Martin, A.J., & Cochrane, D. (2011). Hand–arm strength and endurance as predictors of climbing performance. *European Journal of Sport Science*, *12(1),*16–25. http://doi.org/10.1080/17461391.2010.546431
Bergmann, G., Graichen, F., Bender, A., Rohlmann, A., Halder, A., Beier, A., & Westerhoff, P. (2011). In vivo gleno-humeral joint loads during forward flexion and abduction. *Journal of Biomechanics*, *44*(8),1543–1552. http://doi.org/10.1016/j.jbiomech.2011.02.142

Chromiak, J.A., Smedley, B., Carpenter, W., Brown, R., Koh, Y.S., Lamberth, J.G., Altorfer, G. (2004). Effect of a 10-Week strength training program and recovery drink on body composition, muscular strength and endurance, and anaerobic power and capacity. *Nutrition*, *20*(5),420–427. http://doi.org/10.1016/j.nut.2004.01.005

Chuang, M.-C., You, M., Cai, D., & Chen, C.-C. (1997). Isometric muscle strength of Chinese young males in Taiwan. *Ergonomics*, *40(5),*576–590. http://doi.org/10.1080/001401397188044

Crisco, J. J., Halilaj, E., Moore, D. C., Patel, T., Weiss, A.-P. C., & Ladd, A. L. (2015). In Vivo Kinematics of the Trapeziometacarpal Joint During Thumb Extension-Flexion and Abduction-Adduction. *The Journal of Hand Surgery*, *40*(2),289–296. http://doi.org/10.1016/j.jhsa.2014.10.062

Dummer, G.M., Clarke, D.H., Vaccaro, P., Vander Velden, L., Goldfarb, A.H., & Sockler, J.M. (1985). Age-Related Differences in Muscular Strength and Muscular Endurance among Female Masters Swimmers. *Research Quarterly for Exercise and Sport, 56(2),*97–102. http://doi.org/10.1080/02701367.1985.10608442

Fujiwara, K., Toyama, H., & Kunita, K. (2003). Anticipatory activation of postural muscles associated with bilateral arm flexion in subjects with different quiet standing positions. *Gait & Posture, 17(3),* 254–263. http://doi.org/10.1016/S0966-6362(02)00100-5

Halperin, I., Aboodarda, S.J., & Behm, D.G. (2014). Knee extension fatigue attenuates repeated force production of the elbow flexors. *European Journal of Sport Science*, *14(8),*823–829. http://doi.org/10.1080/17461391.2014.911355

Hassanlouei, H., Falla, D., Arendt-Nielsen, L., & Kersting, U.G. (2014). The effect of six weeks endurance training on dynamic muscular control of the knee following fatiguing exercise. *Journal of Electromyography and Kinesiology*, *24*(5),682–688. http://doi.org/10.1016/j.jelekin.2014.06.004

Hausswirth, C., Argentin, S., Bieuzen, F., Le Meur, Y., Couturier, A., & Brisswalter, J. (2010). Endurance and strength training effects on physiological and muscular parameters during prolonged cycling. *Journal of Electromyography and Kinesiology*, *20*(2),330–339. http://doi.org/10.1016/j.jelekin.2009.04.008

Iermakov, S.S., Adashevskiy, V.M., Sivolap, O.A. (2010). Theoretical and experimental determination of biomechanics descriptions at run. *Physical Education of Students, 4*, 26 – 29.

Kamaev, O.I., Bezkorovainyi, D.O. (2013). Influence of the experimental program of trainings in armsport on the power indexes of basic muscle groups of 16-17-years-old armwrestlers. *Pedagogics, psychology, medical-biological problems of physical training and sports, 1,*34-39. http://doi.org/10.6084/m9.figshare.106936

Kemi, O.J., Rognmo, O., Amundsen, B.H., Stordahl, S., Richardson, R.S., Helgerud, J., & Hoff, J. (2010). One-arm maximal strength training improves work economy and endurance capacity but not skeletal muscle blood flow. *Journal of Sports Sciences, 29(2),*161–170. http://doi.org/10.1080/02640414.2010.529454

Ko, Y.S., & You, S.E. (2015). Comparisons of physical fitness and body composition among Sasang types with and without body mass index as a covariate. *Integrative Medicine Research*, *4*(1),41–47. http://doi.org/10.1016/j.imr.2015.01.002

Nichols, J.A., Bednar, M.S., Havey, R.M., & Murray, W.M. (2015). Wrist salvage procedures alter moment arms of the primary wrist muscles. *Clinical Biomechanics, 30(5),*424–430. http://doi.org/10.1016/j.clinbiomech.2015.03.015

Nicolay, C.W., & Walker, A.L. (2005). Grip strength and endurance: Influences of anthropometric variation, hand dominance, and gender. *International Journal of Industrial Ergonomics*, *35*(7),605–618. http://doi.org/10.1016/j.ergon.2005.01.007

Nosko, M.O., Arkhypov, O.A. (2011). *Biometry of human motor functioning*, Kyiv-Chernigiv: Word.

Pinter, I. J., Bobbert, M. F., van Soest, A. J. Knoek, & Smeets, J. B. J. (2010). Isometric torque–angle relationships of the elbow flexors and extensors in the transverse plane. *Journal of Electromyography and Kinesiology, 20*(5),923–931. http://doi.org/10.1016/j.jelekin.2010.05.001

Podrigalo, L.V., Galashko, M.N., Galashko, N.I. (2013). Study and evaluation of indicators of relationships motor analyzer sportsmen of armsport. *Physical Education of Students, 3,*46-49. http://doi.org/10.6084/m9.figshare.669671

Podrigalo, L.V., Galashko, M.N., Galashko, N.I., Prusik, Krzysztof, Cieślicka, Mirosława (2014). Research of hands' strength and endurance indications of arm sport athletes having different levels of skills. *Physical education of students, 2,*37-40. http://doi.org/10.6084/m9.figshare.907140

Podrigalo, L.V., Galashko, N.I., Galashko, M.N. (2012). Using ergonomic approaches for increasing effect of preparation at arm sport. *Physical Education of Students, 1,*87-90.

Podrigalo, L.V., Galashko, N.I., Galashko, M.N. (2013). Goniometric researches of armwrestling sportsmen. *Physical Education of Students, 1,*45-49. http://doi.org/10.6084/m9.figshare.156357

Podrigalo, L.V., Galashko, O.I., Galashko, M.I. (2011). Biomechanics peculiarities of armwrestling. *Bulletin of the Chernihiv State Pedagogical University*, *91(1),*363 – 365.

Podrigalo, L.V., Istomin, A.G., Galashko, N.I. (2010). *Monitoring of the functional state of the athletes in arm sport*, Kharkov, KNMU Publ.

Potop, V.A., Grad, R., Boloban, V.N. (2013). Biomechanical indicators of key elements of sports equipment gymnastic exercises. *Pedagogics, psychology, medical-biological problems of physical training and sports, 9,*59-72. http://doi.org/10.6084/m9.figshare.751559

Potop, Vladimir, & Cretu, Marian. (2015). Biomechanical characteristics of the synchronization of key elements of sport technique of the complex dismounts off beam. *Journal of Physical Education and Sport (JPES),* 15(2),324-329. http://doi.org/10.7752/jpes.2015.02049

Potop, Vladimir, Timnea, Olivia Carmen, Mihaiu, Costinel, Manole Carmen. (2014). Biomechanical characteristics of back double salto dismount off the uneven bars. *Journal of Physical Education and Sport (JPES),* 14(2),248 - 253. http://doi.org/10.7752/jpes.2014.02037

Romanenko, V.A. (2005). *Diagnostics of motor abilities.* Donetsk: DonNU.

Ryepko, O.O. (2013). Morphological characteristics of elite athletes, specializing in speed climbing, climbing and alpinism. *Pedagogics, psychology, medical-biological problems of physical training and sports, 12,*67-71. http://doi.org/10.6084/m9.figshare.880621

Smets, M.P.H., Potvin, J.R., & Keir, P.J. (2009). Constrained handgrip force decreases upper extremity muscle activation and arm strength. *Ergonomics*, *52(9),*1144–1152. http://doi.org/10.1080/00140130902919113

Song, M.-S., Yoo, Y.-K., Choi, C.-H., & Kim, N.-C. (2013). Effects of Nordic Walking on Body Composition, Muscle Strength, and Lipid Profile in Elderly Women. *Asian Nursing Research*, *7*(1),1–7. http://doi.org/10.1016/j.anr.2012.11.001

Sung, D.J., Park, S.J., Kim, S., Kwon, M.S., & Lim, Y.-T. (2014). Effects of core and non-dominant arm strength training on drive distance in elite golfers. *Journal of Sport and Health Science.* http://doi.org/10.1016/j.jshs.2014.12.006

Werlauff, U., & Fynbo Steffensen, B. (2014). The applicability of four clinical methods to evaluate arm and hand function in all stages of spinal muscular atrophy type II. *Disability and Rehabilitation, 36(25),*2120–2126. http://doi.org/10.3109/09638288.2014.892157

Yamazaki, Y., Suzuki, M., Ohkuwa, T., & Itoh, H. (2003). Coactivation in arm and shoulder muscles during voluntary fixation of a single joint. *Brain Research Bulletin, 59(6),*439–446. http://doi.org/10.1016/S0361-9230(02)00952-8

Yung, M., & Wells, R.P. (2013). Changes in muscle geometry during forearm pronation and supination and their relationships to EMG cross-correlation measures. *Journal of Electromyography and Kinesiology*, *23*(3),664–672. http://doi.org/10.1016/j.jelekin.2013.01.001

Zosimov, A.N. (2000). *Analysis of the systems in medicine*, Kharkov, Tornado.

-- 537

JPES ®   www.efsupit.ro