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Influence of Strength Abilities on Quality of the Handstand

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Abstract—The contribution deals with influence of strength abilities on quality of performance of static balance movement structure – handstand. To test the strength abilities we selected following tests: number of push-ups per minute and persistence in trunk backward bend in sitting position. We tested the dependent variable by three tests – persistence in handstand position on a stabilometric platform, persistence in handstand position and evaluation of quality of handstand performance. Pearson's correlation coefficient was used to formulate the relationship between variables. The results showed a statistically significant dependence using which we deduced conclusions for training practice.

Keywords—Strength abilities, handstand, balance.

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I. Introduction

A CHANGE in results in sport gymnastics in recent years has resulted in a considerable shift in a content of routines. This leads to an increase in difficulty which is becoming a priority. In order to execute movement structures of the highest level of difficulty, it is important to manage the basic movement structures on a perfect level. We will focus on the inner essence of the technique exhibition of the basic structure of nearly every gymnastic discipline – handstand. Performance of this balance structure in sport gymnastics is often made difficult by gymnastic equipment conditions (handstand on parallel bars, balancing beam), whose mechanical characteristics and stability influence the difficulty of balancing [1]. The difficulty is also increased by a fact that at these conditions the centre of gravity gets out of the supporting base already due to small deflection.

Many authors have already dealt with the process of balancing in handstand position [2]-[5]. In their research on handstand authors use the mechanism of balancing in an upright position. The body composition during handstand is similar to the one in upright position, this means that transfers appear between upper and lower extremities [6]. Handstand is characterized by following differences compared to upright position: The area of supporting base is smaller, whereas the distance between the base and the centre of gravity due to support in extended arms which increases the instability [7]. More authors have dealt with deeper analysis of balancing strategies in handstand position from mechanical point of view, their opinions, however, are not uniform. Nashner and McCollum [8] state that configuration in handstand position is different from the one in upright position as instead of three there are four joints involved (wrists, elbows, shoulders and hips) and this requires specific postural coordination. Similarly, Asseman et al. [9] is of the same opinion when stating that balancing in handstand position is more complex as four joints are involved instead of three. From the point of view of balancing strategies in handstand position Sobera [4] found out that the most significant corrections are done in wrist joints: "Regulation of balancing in handstand position is conducted similarly to upright position, i.e. thanks to replacement of COP (centre of pressure) towards fingers or wrist joints in sagittal plane or right/left in frontal plane. Balancing in handstand position requires maximal balancing in wrist joints. Regulation of balance in this, for a common person unnatural position of handstand, is done mainly thanks to increase in pressure of fingers onto the base when centre of gravity moves towards fingers, or increase in pressure under the wrist joints when centre of gravity moves towards these joints." Yedon and Trewarthe [10] confirm the most significant activity in wrist joints when the perturbations in sagittal plane are corrected by flexors and extensors in wrists with synergicly cooperating shoulder joints and hips ensuring the maintenance of fixed body configuration. Rotation in wrists together with rotations in shoulders and hips generally work in the same direction as the direction of rotation in wrists. These results are the same as results of Kerwin and Trewarth [3] who found out that rotations in wrists, shoulders and hips significantly correlate with the shift of centre of gravity, and the movement in wrists was dominant. Research results of Gautier et al. [11], where he analyzed a balancing strategy in handstand position in gymnasts, showed considerable movement in shoulders, angle (arms-trunk) (8.56º) and wrists, angle (fingers-arms) (12.39º), elbows nearly did not change the angle (forearm-upper arm) (1.21º), but reached max perturbations, and hips hardly changed the angle (trunk-lower extremities) (0.88º). A different technique involving the flexion in elbow joint recorded Slobounov and Newell [7]. According to Yedon and Trewarth [10], the flexion strategy is probably used when balancing using the "wrist strategy" is unsuccessful. Gautier et al. [5] explains that the flexion in elbow joints enables the gymnasts a quick

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lowering of centre of gravity in case of extreme imbalance, similarly as the knee joints fulfills this function in upright position. The result is bigger tolerance to perturbations and possibility to gain balance again. Configuration in handstand position is thus similar to one in upright position with wrists having similar function as ankles, elbows represent knees and shoulders represent hips.

We tend to think that during handstand position body is in an upside down position and equivalents of ankles and hips in upright position are wrists and shoulders. A correct technique of performance can be described as a three-segmental strategy of correcting balance in handstand position. The tendency is to maintain a perfect stabilization of body by isometric contraction of abdominal, gluteal and back muscles resulting in connection of segments legs – trunk and correction takes place at level of wrist – shoulder. Handstand requires an extraordinary muscle activity of upper extremities whose activity has an antigravity role. Although the muscle activity of upper extremities is more precise compared to lower extremities, they succumb to fatigue more easily. As handstand position is included in routines of sport gymnastics repeatedly, an extraordinary level of strength abilities is required for upper extremities. From this reason this study deals with how limiting the level of strength abilities is for optimal performance of handstand.

II. Aims and Methods

This study is realized as an empiric research. It is a case of correlation study. We investigate relationships between strength abilities and selected movement structure in sport gymnastics which is difficult for maintaining balance – handstand.

A. Characteristics of a Tested Group

We tested 19 women sport gymnasts aged 10 to 13. All tested sportswomen compete at a national level and have qualified to the highest national competition. They train with different trainers in the same sport club 5 times a week for 3 to 3.5 hours. Every training unit includes 30 min of motoric preparation whose component is exercising in handstand position, 45 minutes on balance beam and parallel bars and 45 minutes of acrobatics or 30 minutes vault. Once a week the gymnasts have 60 minute of ballet preparation. There are performance differences among tested sportswomen, which is obvious considering the number of tested people. Due to different levels of performance we selected elementary tests which should be managed at a optimal level by all gymnasts. We focused on the inner essence of the observed event.

B. Aim

Our aim is to find out to what extent the differences in levels of strength abilities of arms and trunk muscles will influence the quality of performance of selected static movement structure of sport gymnastics – handstand.

C. Hypothesis

The level of stability in handstand position depends on level of strength abilities.

D. Operationalization of Variables

Based on the hypothesis, individual variables are operationalized:

Independent variable – level of strength abilities (Tests: number of push-ups per minute, persistence in trunk backward bend in sitting position – sec.)

Dependent variable – level of stability in handstand position (Test: quality of performance of handstand – point penalization for faults, persistence in handstand position, measured parameter – time, handstand on stabilometric platform, measured parameter – COP trajectory)

E. Methods of Acquiring the Data

Based on the study of professional literature we selected following tests:

1. Tests of Strength Abilities

Number of Push-Ups per 1 Minute

This motoric test tests endurance strength abilities of arms and shoulder girdle and strength of extensors of arms.

Description:

The person lying on the abdomen bends arms and leans them with palms on the ground (fingers pointing forwards) at level of breasts, chest is in the contact with the base. Then he outstretches arms and executes press-up (trunk and legs creating a straight line). When executing the push-up, the abdomen gently touches the base. He tries to execute the highest number of push-ups in a minute. The supervising person interrupts the exercising when the exerciser starts to bend forward or backward, eventually when he doesn't rise to extended arms [12] (reliability r = 0.85).

Persistence in Trunk Backward Bend in Sitting Position

The test reveals the ability of static strength of trunk, mainly abdominal muscles [13], [14].

Description:

Sit with bent knees (angle between shanks and thighs is 90°), legs fixed to ground, arms rising upward from inner side, hands to back of the neck – back-bend (angle between trunk and ground max. 40°), persistence in back-bend. We evaluated the time, how long the tested person persists in the position (reliability r = 0.88).

2. Test of Static Balancing Ability - Handstand

Persistence in Handstand Position on a Stabilometric Platform

Description:

With the help of an assistant, the sportswoman performs a handstand on a stabilometric platform. When the assistant releases the exercising person, a measurement begins when during a period of 10 s the measuring device registers the

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COP trajectory. The test is repeated 5 times. An average value is calculated from all attempts. The test is not standardized.

Device:

Stabilometric system FITRO Sway check is a dynamometric platform with four tenzometric force sensors connected to a computer with a special program (Fig. 1). This system enables measuring the movement of point of resulting contact force in the horizontal plane based on the distribution of vertical force registered by the tenzometric sensors with frequency of 100 Hz. The system is able to monitor the deviations of COP (centre of pressure) with accuracy of 0.1 mm. During the stabilometric measurement we acquire average values of individual parameters, values in given time period with interval of seconds, or with interval of milliseconds. The device enables to evaluate a statokinesiograph which registers the body deviations in time expressed in right-left (COP-X) and anteposterior plane (COP-Y).

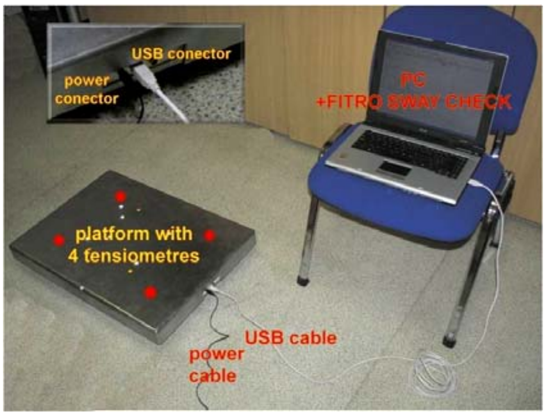

Fig. 1 System for stabilometric measurement

Many authors have dealt with the reliability of tests of static balance on stabilographic platform [15]-[17]. Based on this research we consider the use of stabilometric system FITRO Sway check to be an objective and reliable method of detection of balancing abilities of lower extremities. Zemková and Hamar [16] recommend an average speed of COP deviations as the most reliable parameter of balancing ability (reliability coefficient r = 0,819). Although we evaluated the total trajectory covered by the point of resulting contact force in given time, it is obvious that this parameter is directly proportional to an average speed ($d=v \times t$). Therefore we consider the parameter to be as reliable as the average speed of deviations.

Persistence in handstand

Description:

This is not a standardized test. The sportswoman from the initial position of heelstand performs by stepping forward a handstand. The time measured is from the moment of acquiring the position of handstand till she leaves this static position. The gymnast cannot correct the body deviations by hand shift.

Test of Handstand Performance

Description:

This is not a standardized test. The quality of performing the movement structure – handstand – is assessed from the technical point of view as well as from the point of view of rules of sport gymnastics, assessed by an international referee of sport gymnastics. We assessed the extent of fault by 4 grade scale: 0 no fault, 0.1b small fault, 0.3b medium fault, 0.5b big fault, where the fault size is defined as the size of angular deviation from the perfect performance. We calculated an average value from 5 attempts.

Methods of Results Evaluation

We evaluated the obtained data using mathematical-statistic methods. We found out the basic statistical parameters for every measured characteristic – arithmetic mean, median, range of variation, standard deviation, etc. To evaluate the hypothesis we investigated interindividually the dependence between the variables. We calculated the Person's correlation coefficient. The results are at a level of significance of 5%.

III. Results

A. Tests of Strength Abilities

We conducted the tests of strength abilities to verify to what extent the level of strength abilities influence the quality of performance and level of stability as well as the duration of persistence in handstand position.

We selected test with push-ups and test of persistence in trunk backward bend in sitting position to evaluate the strength abilities. Graph (Fig. 2) shows the results of the strength test with push-ups. Initially we were deciding between push-ups and chin-ups, and after analyzing the handstand from kinezilogic point of view we came to a conclusion that triceps participate more in balanceng strategy during handstand, therefore we chose push-ups.

Number of push-ups done by the probands in 1 minute was between 24 and 47. The average value = 36.26 push-ups, the standard deviation ± 6.94 push-ups and variation coefficient = 0.19.

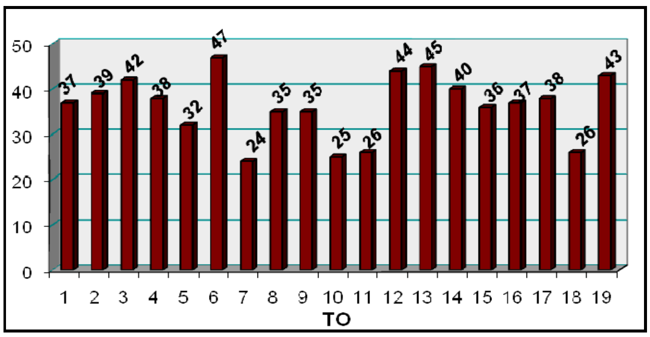

Fig. 2 Graph of results of strength test – push-ups

Fixation of connection of segments lower extremities and trunk is an initial prerequisite which must be fulfilled in order

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to use the strength of upper extremities effectively. From kinesiologic point of view the fixation of body segments is realized mainly by isometric contraction of abdominal muscles which is best tested by persistence in trunk backward bend in sitting position. As we can see in the graph (Fig. 3), the results were between 35s and 187s. In average the tested sportswomen persisted in the backward bend for 99.42s, standard deviation equals to ± 39.83s and variation coefficient 0.4. Bigger differences in this test results may be caused by the will characteristics of the tested persons, however, all gymnasts showed a sufficient level of isometric activity of abdominal muscles (average of common population 55-56s, sport gymnast 71s).

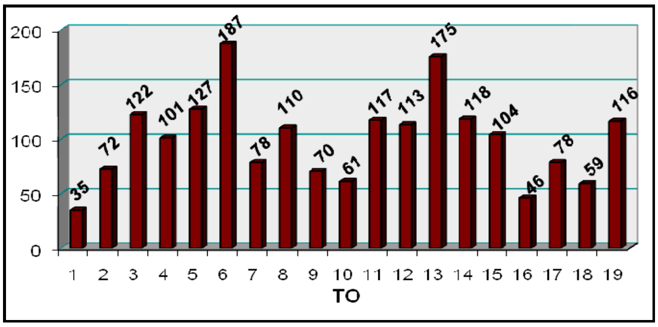

Fig. 3 Graph of results of strength test – persistence in trunk backward bend in sitting position

B. Tests of a Static Movement Structure - Handstand

We tested the optimality of its performance by three tests – we evaluated the quality of performance of handstand, duration of persistence and size of COP deviations when balancing in the handstand position.

To verify the quality of handstand every attempt was assessed by an international referee using 4-grade scale. The point deduction corresponded to the size of fault: no fault 0, small fault 0.1, medium 0.3, and big 0.5. We calculated an average value from all attempts.

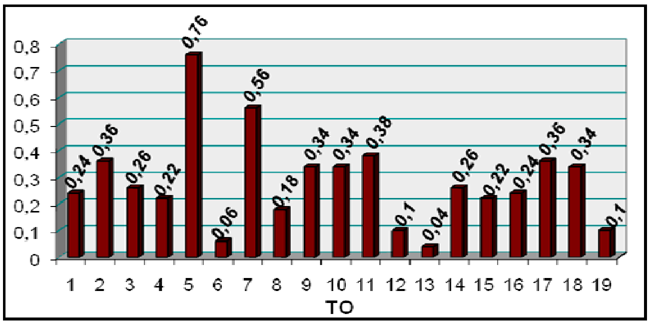

Fig. 4 Graph of evaluation of quality of handstand

Graph (Fig. 4) shows that the average values were between 0.04 and 0.76 points. Considering the quality of handstand, average gymnasts performed the handstand with medium size fault, which corresponds to an average value of 0.28 points calculated from all gymnasts' attempts. Quite a big standard deviation was calculated, ± 0.17 point, which is 60.7% from the average value. This reflects a big variability of quality of handstand, we can therefore say, and that from this point of view, the tested group is quite heterogeneous.

Graph (Fig. 5) shows how big is the gymnasts' ability to perform handstand without help with the longest possible duration. The measured values were between 1.4s up to 37.4s. In average, the gymnasts persisted in handstand for 19.97s. The standard deviation ±11.39s reaches 57% from the average value. Similarly to the previous test, the high value of variation coefficient shows high result variability.

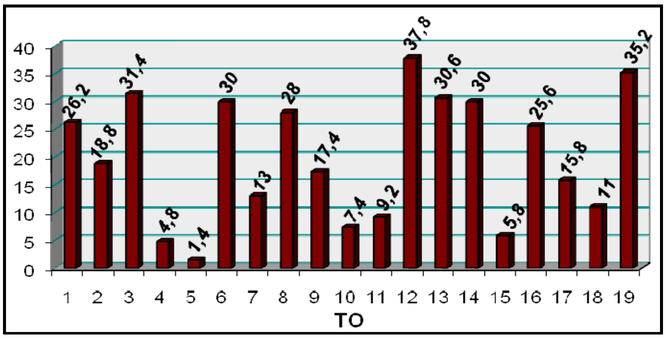

Fig. 5 Graph of persistence in handstand position

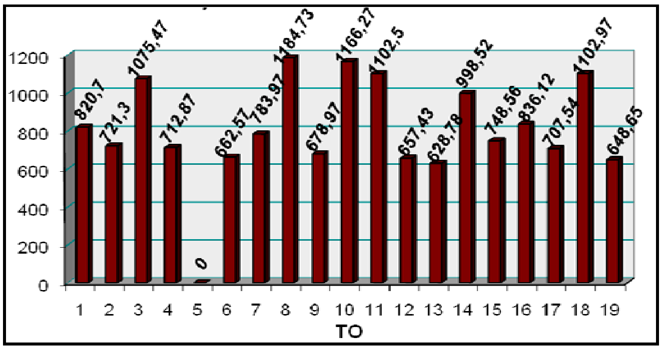

Fig. 6 Graph of COP deviations during handstand on a stabilometric platform

One gymnast (TO4) did not manage to persist in handstand on a stabilometric platform for required time period – 10s, therefore we had to remove her form evaluation of certain results. As the graph (Fig. 6) shows, the measured values in this test were between 628.78mm and 1184.73mm. Average value of COP deviation was 802mm. The standard deviation was ± 274.24mm and the variation coefficient 0.34. If we were to compare the results of both tests on a stabilometric platform, test of an upright position on one leg and test in handstand position, the average COP trajectory in handstand is by 503.74mm bigger, thus 2.7 times bigger than the average COP trajectory in upright position on one leg. This difference confirms the fact that from biomechanical point of view handstand is more instable than stand on one leg.

In following Table I is conducted basic static characteristics of results of individual tests which were conducted and described above.

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TABLE I
GENERAL RESULTS AND BASIC STATIC CHARACTERISTICS OF INDIVIDUAL TESTS

	Push-ups	**Persistence in tbb**	**stab hst**	**persistence hst**	**quality hst**
x	36.263	99.421	802	19.968	0.2821
d	±6.943	±39.827	±274.24	±11.387	±0.1723
vk	0.1915	0.4006	0.3419	0.5702	0.6107
min	24	35	628.72	1.4	0.04
max	47	187	1184.7	37.8	0.76

Legend of abbreviations in the table:
Push-ups : Test of push-ups per 1 minute
Persistence in tbb : Persistence in trunk backward bend in sitting position
stab hst : Stabilometry in handstand
persistence hst : Persistence in handstand
quality hst : Quality of handstand

IV. DISCUSSION

Firstly we investigated the normality of data distribution. Next calculations were selected for normal data distribution. We tested the method with abnormal distribution, but the differences were minimal and did not influence any of the statistically significant dependence.

In Table II, we show the values of Person's correlation coefficient for relationships between individual variables.

TABLE II
RESULTS OF PEARSON'S CORRELATION

	Stab hst	**Push-ups**	**Persistence in tbb**	**Persistence in hst**	**Quality hst**
Stab hst	x				
Push-ups	-0.3008	x			
Persistence in tbb	-0.2752	0.5334 0.0093	x		
Persistence in hst	0,1378	**0,718** **0.0003**	0,2947	x	
Quality hst	-0,3019	**-0,687** **0,0006**	-0,338 0,0783	**-0,693** **0,0005**	x

In hypothesis we investigated how significant is the assumption of strength abilities for performance of handstand. The independent variable is the level of strength abilities which was evaluated using two strength tests which were firstly compared to each other. Push-up test focused on strength abilities of upper extremities and test of persistence in trunk backward bend in sitting position tested the strength assumption of trunk, more precisely abdominal muscles.

TABLE III
STATISTICAL EVALUATION OF THE RELATIONSHIP BETWEEN THE TESTS PUSH-UPS AND PERSISTENCE IN TRUNK BACKWARD BEND IN SITTING POSITION

Pearson's correlation	0.5334
95 % confidential interval	0.1045 <> 0.7950
t-statistics	2.6001
Degrees of freedom	17,0000
One side probability	0.0093

Medium strong dependence was confirmed (Table III). We assume that this is caused by the complexity of the training process of sport gymnasts. The variability of exercises on apparatus requires precise functional preparation during which none of the body parts can be missed out which would then cause disruption of the chain of cascading parts. Based on the test results we can say that if gymnastics has some strength assumptions, there are no big differences among muscle groups. Push-up test is more valuable for handstand performance; therefore we use it as an independent variable for solving the hypothesis. Using the test of persistence in sitting position we made sure that gymnasts have sufficient ability to isometrically fix the trunk. Therefore they fulfill the demands which are laid to abdominal muscles to perform the handstand with high quality.

Persistence in handstand is a dependent variable in the hypothesis. We operationalized this variable from many points of view. We were interested in the relationship between the quality performance of handstand which was assessed by an international sport gymnastics referee and the persistence in handstand. Although according to rules of sport gymnastics the required time of persistence in handstand which finishes many movement structures is only 2 seconds, we consider the ability to persist in this inverse position for longer period very important. From this reason we tested the maximum persistence in handstand. Here we talk about mastering the basic movement structure with the most perfect technique possible, by which we mean the most economical mastering of the structure. For women sport gymnasts a perfect mastering of handstand is a basic prerequisite for basics of acrobatics which is then transferred to balancing beam. Without perfectly mastered handstand the top gymnasts are unable to realize such progress which is required by current trend. This essential prerequisite of achieving the best performances in sport gymnastics can be supported by a proved practice of Chinese, Rumanian and Russian women sport gymnasts [26]. Already the youngest gymnasts perform several-minute persistence in handstand with emphasis on the technique of performance. Deeper understanding of the relationship between the two variables, quality and persistence in handstand, may help us to understand the relationship between handstand and strength abilities, which is the matter of the hypothesis.

TABLE IV
STATISTICAL EVALUATION OF THE RELATIONSHIP BETWEEN THE QUALITY OF HANDSTAND AND PERSISTENCE IN HANDSTAND POSITION

Pearson's correlation	-0.6930
95% confidential interval	-0.8725 <>-0.3484
t-statistics	-3.9629
Degrees of freedom	17,0000
One side probability	0,0005

A strong negative dependence was shown for these two variables (Table IV). Simply, the one who performs a technically perfect handstand has the lowest point deductions due to faults and persists in the position for longer period. Statistical result points to the fact that it is not possible to persist in handstand for sufficient period of time without mastering the perfect technique of this movement structure. However, based on many year of both competition and trainer practice, from logical point of view, we assume that this dependence is not bilateral. This means that not every gymnast able to perform a perfect handstand persist in the position long enough. In our opinion, the gymnast falls if he lacks sufficient muscle strength to correct the COP deviations. How the persistence in handstand, apart from its quality, is influenced by the strength abilities is shown in the following table.

TABLE V
STATISTICAL EVALUATION OF THE RELATIONSHIP BETWEEN THE PUSH-UP TEST AND PERSISTENCE IN HANDSTAND

Pearson's correlation	0,7180
95% confidential interval	0,3915 <> 0,8839
t-statistics	4,2533
Degrees of freedom	17,0000
One side probability	0,0003

Statistical evaluation shows strong dependence (r = 0.7180) (Table V) of persistence in handstand position on strength abilities of upper extremities, thus the number of push-ups done by the gymnast per minute. We came to similar conclusion with the comparison of the test of quality of handstand with test of strength abilities.

TABLE VI
STATISTICAL EVALUATION OF RELATIONSHIP BETWEEN THE PUSH-UP TEST AND QUALITY OF HANDSTAND

Pearson's correlation	-0,6869
95% confidential interval	-0,8698 <>-0,3382
t-statistics	-3,8972
Degrees of freedom	17,0000
One side probability	0,0006

A strong negative dependence (r = - 0.6869) (Table VI) shows that disregarding the persistence in handstand, also quality of handstand is to some extent influenced by strength of upper extremities. These results confirm the opinions of other authors who state that with the strength development the balance abilities reinforce [18]-[25].

To verify the influence of strength abilities on level of stability and technique of performance of handstand and to understand the system between the researched variables and their relationship more precisely we compared the tests quality of performance of handstand with the test stabilometry of handstand.

TABLE VII
STATISTICAL EVALUATION OF THE RELATIONSHIP BETWEEN THE QUALITY OF HANDSTAND AND STABILOMETRY OF HANDSTAND

Pearson's correlation	-0,3019
95% confidential interval	-0,6650 <> 0,1765
t-statistics	-1,3059
Degrees of freedom	17,0000
One side probability	0,1045

TABLE VIII
STATISTICAL EVALUATION OF THE RELATIONSHIP BETWEEN THE PERSISTENCE IN HANDSTAND AND STABILOMETRY OF HANDSTAND

Pearson's correlation	0,1378
95% confidential interval	-0,3376 <> 0,5571
t-statistics	0,5735
Degrees of freedom	17,0000
One side probability	0,2869

Tables with results show that neither the tests quality of handstand – stabilometry of handstand (r = - 0.3019) (Table VII), or tests persistence in handstand – stabilometry of handstand (r = 0.1378) (Table VIII) prove any statistically significant dependence. We explain this fact by using the potential of strength abilities when performing the handstand itself. Persons disposing of bigger strength may dare conduct correcting movements in bigger extent maintaining a perfect technique of handstand and choose a three-segmental strategy at level of hand – arm – trunk with lower extremities. In contrast, persons less disposing of strength abilities use the three-segmental strategy for limited period only and then replace it with four-segmental strategy which works at level hand – arm (with extremes of antebrachium and upper arm), trunk – lower extremities. Such performed correcting movements are not only penalized regarding the performance of the structure, but it is also impossible to balance the body with this number of degrees of freedom.

On the other hand, strength can be partially substituted by balance, but here we talk about an individual with high level of balancing abilities with a high portion of neuromuscular coordination. As trainer practice shows there are extremes both confirming and destroying both theories about factors influencing handstand. There are gymnasts who had very good strength abilities, but were unable to perform handstand or exercise on balancing beam. On the other hand there are gymnasts without strength abilities with a sense for movement who managed handstand with perfect easiness.

V. CONCLUSIONS

Influence of strength on persistence in static positions is proved by Person's correlation coefficient 0.718 at the level of significance 0.0003 for the dependence of the duration of persistence in handstand on the number of push-ups per 1 minute. This strong dependence is proved also by r = -0.6869 at the level of significance 0.0006 for dependence of quality of performance of handstand on strength abilities of upper extremities. We therefore accept the hypothesis that the strength of corresponding muscle groups is a limiting factor for balancing in a difficult static position, where handstand belongs. From logical-pragmatic point of view we came to conclusions for practice. Gymnasts with better strength abilities may dare doing the correcting movements in bigger extent, thus with bigger COP deviations, but they usually choose a three-segmental balancing strategy. Gymnasts less disposing of strength abilities use the three-segmental balancing strategy exceptionally and for shorter period of time. Their correcting movements are done based on four-

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segmental strategy which results in worse quality of performance of handstand.

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