FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 14, N° 1, 2016, pp. 51 - 62

A review article

SYSTEMATIZATION OF PREVIOUS RESEARCHES OF EXERCISES ON PARALLEL BARS

UDC 796.41:615.851

Saša Veličković[1], Miloš Paunović[1], Vladan Vukašinović[2]

[1]University of Nis, Faculty of Sport and Physical Education Nis, Nis, Serbia
[2]University of Belgrade, Faculty of Sport and Physical Education Belgrade, Belgrade, Republic of Serbia

Abstract. *Parallel bars is one of the six apparatus of men's artistic gymnastics all-around, based on the great variety of elements performed on this apparatus, as well as of the performing styles and ways of their training. The aim of this paper is to analyze previous studies on parallel bars exercises, and the systematization of research papers related to parallel bars exercises. In code of points (COP) for judging, as many as 168 elements are shown (FIG, 2015) which are performed and which must be performed at competitions on parallel bars. In previous studies there are only 22 elements (13.5%) and they were mainly related to the analysis of the performance techniques of the above mentioned elements. There are no studies dealing with the methodical process of achieving the ideal execution of an element. This only points to the fact that the studies on parallel bars exercises, although conducted over a long period of time, are still in their infancy. Considering the great perspective of elements and the possibility of their upgrade, it is necessary to start with the stuides of elements which are performed through support on the upper arms.*

Key words: *artistic gymnastics, parallel bars, systematization*

INTRODUCTION

In artistic gymnastics, around 5000 exercises are performed, grouped into various structural groups. In the current COP for evaluation of the International Gymnastics Federation for the men's gymnastics (FIG, 2015) are evaluated by complexity approximately 1000 exercises, different coordination complexity, grouped on six gymnastic apparatus of mens all-around. The parallel bars is one of the six apparatus of men's gymnastics all-around competition, where there are currently 168 elements divided into 5 structural groups (Group I

Received October 15, 2015 / Accepted March 14, 2016
Corresponding author: Saša Veličković
University of Niš, Faculty of Sport and Physical Education, Čarnojevića 10a 18000 Niš, Serbia
Phone: +381 18 510900 • E-mail: v.sale70@gmail.com

– Elements in support or through support on two bars; Group II – Elements starting in the upper arm position; Group III – Long swings in hang on one or two bars; Group IV – Underswings and Group V – Dismounts). The modern competitive composition on this apparatus contains mostly elements of swing and elements with a flight phase selected from different groups, which are performed with transitions from different positions of support: support on upper arms and hangs, on one or two bars, in the lateral and frontal position. The aim is to show the potential of this apparatus and the ability of competitors (FIG, 2015).

Considering the great variety of elements performed on this apparatus, as well as performing styles and ways of their training, there are a variety of studies that have been conducted. There is a need to systematize all previous studies and identify the directions for further studies. The first individual to deal with the systematization of previous researches in artistic gymnastics was Prassas (1999), who classified gymnastic elements into five categories: 1) pushing from a hard or elastic surface, 2) rotation in a vertical plane around a fixed or flexible horizontal axis of rotation, 3) rotation in a vertical plane around a vertical axis of rotation, 4) rotation in unsupported phase, and, 5) dismounts. The author points out that the research on parallel bars is not extensive (Table 1). Basket to handstand was studied by Takei, Dunn, Nohara, & Kamimura (1995) who compared the (traditional) inner and (newer) the outer grip of bars in the realization of basket to handstand. Quasi-static movement and press to handstand were studied by Prassas et al. (1986). Prassas (1994, 1995) also examined techniques of two basic elements: the somersault backward to a handstand and back flip dismount. The dynamics of both elements were studied by Prassas & Papadopoulos (1998). Finally, a case study of double back somersault dismount was presented by Manon & Deleva (1993a), who also investigated the different kinds of forward somersaults.

Table 1 Review of biomechanical researches into men's artistic gymnastics (Parallel bars – Prassas, 1999)

Analyzed element on the apparatus	*Information provided by research*
Somersault backward to handstand	The initial speed, torque, position of the body, the dynamics of the front swing
Basket to handstand	Positions of the body and body parts, speed and angular speed, the differences between the inner and outer grip
Somersault forward and backward on the parallel bars	Linear and angular speed of the swing
Dismounts (*stretched somersault backward, double tucked and piked somersault backward)*	The initial speed, moment of inertia, dynamic of swinging, positions and angles of the body parts

Prassas, Kwon & Sands (2006) indicated that the biomechanical researches in artistic gymnastics has grown considerably in the past few years. However, most researches are still focused on several attempts of generalization. Consequently, the understanding of principles and basis of this sport, although improved, remain marginal with gaps in the knowledge pertaining to technical characteristics of movement throughout this sport. The

authors provided guidance for future biomechanical researches in artistic gymnastics in relation to the collection of data during the two-dimensional and three-dimensional recording, image size, as well as the method of analysis of obtained results, description, simulation and optimization, and statistical procedures. The authors suggested that researches on the parallel bars are not extensive. Gervais & Dunn (2003) came to the conclusion that with a successful dismount there is a larger vertical acceleration when leaving the bars, but smaller angular momentum than with less successful dismounts. Kolar, Andlovic, & Stuhec (2002), who investigated the forward somersault on the parallel bars and came to the conclusion that the preparation swing is the most important swing for execution of the forward somersault.

The aim of this study is to analyze and systematize previous researches related to exercises on the parallel bars. In this study a descriptive method was used – observation. Scientific articles that were analyzed were collected on the internet by searching the electronic publication of scientific journals in the databases of KOBSON, Mendeley, PubMed and Google Scholar. During the search the following key words were used that are related to the type of experimental treatment, the sample of respondents and outcomes of experimental treatments: artistic gymnastics, parallel bars, exercises on parallel bars.

SYSTEMIZATION BASED ON QUANTITY OF PAPERS

This study included a total of 32 studies from the period from 1986 to 2013. For that period it was noted that a maximum of four studies were published in one year.

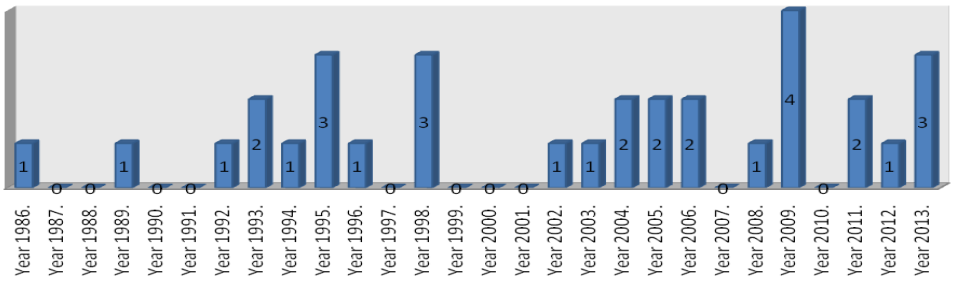

Fig. 1 Number of studies per year

Thirteen journals were registered where the papers were published on the above mentioned issues, of which eight magazines had the prefix "biomechanics" in their name . This observation suggests that most of the studies are of a biomechanical character and related to the analysis of the performance of element techniques. Most of them were published in the proceedings of the conferences of the International Symposium of Biomechanics in Sports. In these proceedings, a total of 10 papers were published. After the mentioned symposium, most of them were published in the Journal of Biomechanics, five papers, and in the Journal of Applied Biomechanics, four papers. In all other journals three or fewer papers were published (Figure 2).

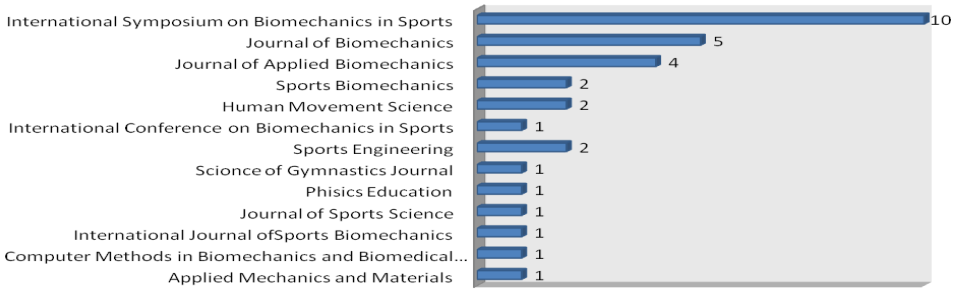

Fig. 2 Number of papers per journals

SYSTEMIZATION BASED ON THE SUBJECT OF RESEARCH

The subject matter of the studies on exercises on parallel bars is quite diverse for the analyzed period (Figure 3). In relation to all included studies, 35% (12 studies) treat the problem of elements performed through the underswing (Underswings). After this group of elements, in a slightly smaller percentage (23% - eight studies) we find studies of elements that are performed by passing through the hang (long swings and a hang on one or two bars) and elements that are performed from a support position (elements in support or through support on two bars – 18% - six studies). The rest of the studies (by 12% or four studies) treated the fifth specific requirement (dismounts) and other problems related to the construction of apparatus and injuries. There were no studies of elements from the second group (Elements starting in upper arm position). The aforementioned results are partially consistent with the analysis of Prassas (1999), which states that the most frequently investigated elements include: the somersault backward to handstand, basket to handstand, somersaults backward and forward on parallel bars and dismounts (stretched somersault backward, double tusked and piked somersault backward). Only two studies treated the parallel bars as the apparatus, and the importance of elasticity of the bars on the efficiency of exercises on parallel bars (Gros, Leikov, & Heisel, 1992; Naundorf, Knoll, & Brehmer, 2009).

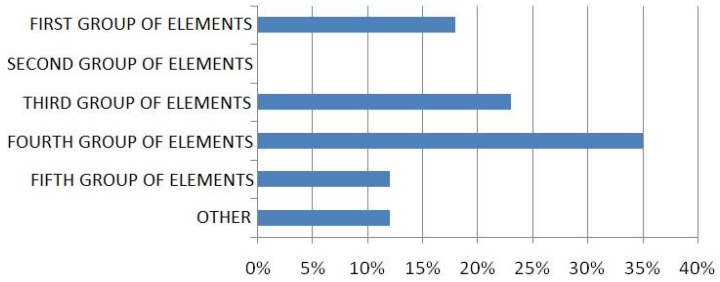

Fig. 3 Subject of research in percents

The first group – elements in support or through support on two bars

The following differences were studied:

1. different somersaults performed in support (Manoni & De Leva, 1993b);
2. wherein it was established that the maximum value of all the analyzed kinematic parameters was determined for the most difficult exercises (double somersault forward tucked to upper arm support);
3. the dynamic phase of swing forward which is performed due to the stretched somersault backward and stretched somersault dismount;
4. 5/4 somersault forward straddled to support and swing backward as a preparation for the mentioned element (Kolar et al., 2002 – where it was noted that during the swing in performing 5/4 somersault forward straddled to support, power and torque are significantly greater than with the preparation swing);
5. successful and unsuccessful attempts of execution of stretched somersault backward (Prassas, 1994 – wherein the identified kinematic parameters are in the highest correlation with the marks given by qualified judges);
6. strength element, press to handstand with stretched arms (Prassas et al., 1986 – the torque measurement could not specify the source of errors for gymnasts who have difficulties learning and performing the analyzed strength element);
7. in addition to the above mentioned procedure, there is also the mathematical modeling of the elements of the swing in support on parallel bars and the system gymnast-bars (Linge, Hallingstad, & Solberg, 2006).

If we look at all the elements from first group that are represented in the COP (FIG, 2015), it can be seen that only 20% of the total number of elements (29 elements) were studied.

The second group – elements performed in support or through upper arm support

No research has been recorded that examines this group of elements, while in the COP as many as 27 of these elements are represented.

The third group – elements performed through a hang

Researches of this group of elements on the parallel bars are directed in the following directions:

1. One group of studies deals only with the glide kips, or elements where the post active transfer of kinetic energy from the legs to the torso is represented (Popov, 1989). The focus is primarily on the following elements: glide kip and casts to hang. Prassas et al. (2008) conducted research in order to examine the factors that affect the result of successful execution of the glide kip on the parallel bars, where the performance was evaluated by qualified judges. The authors present a system of kinematic parameters which explain the evaluation of the judges with 72%.
2. The second group of studies deals with the giant swing or Kenmotsu element, through a comparison of successful and unsuccessful attempts or by comparison with giant swings to other apparatus. Prassas, Ostarelo, & Inoraj (2004) have dealt with the problem of kinematics of giant swing, comparing successful and unsuccessful attempts, and concluded that the success/failure in the realization of giant swing

on the parallel bars can be more sensitive to the timing of actions of gymnasts than to any other issue. Tsuchiya, Murata & Fukunaga (2001) compared giant swing on the parallel bars with giant swing on the high bar and concluded that for effective training of giant swing on the parallel bars the coach must take into account the characteristic differences between apparatus. Giant swing on the parallel bars is compared with giant swing on other apparatus in the research Prassas and Ariel (Prassas & Ariel, 2005; Prassas, 2011), which state that with a few exceptions, the results of the research on giant swing on the parallel bars reveal similar patterns of movement with forms of movement of giant swing on other apparatus. Marked differences are seen in the patterns of movement of the knee, elbow and radio ulnar joint, which is attributed to the limitations imposed by the design of apparatus.

3. One comprehensive study took into account the problem of comparing certain kinematic characteristics of seven exercises on the parallel bars that are performed by passing through a hang on two bars, the difference between the elements (Bolkovic & Cuk, 1995). They concluded that the speed of CBG (center of gravity of the body) is lower during exercises of lower difficulty values, gradually increased with the difficulty of the exercise and is the largest with the most difficult exercises. Also the speed of the CBG in the preparatory phase is significantly higher during exercises with bent knees.

From a total of 32 elements in this group, which are represented in the COP, eight elements were explored, which is approximately 25%. The most common are studies of giant swing.

The fourth group – underswings

It examines the problems linked exclusively to the element of basket to handstand. Only one study deals with swing in the underhang (Delignières, Nourrit, & Micaleff, 1998).

The research of the element basket to handstand can be systematized into studies dealing with the kinematic analysis and descriptions of technique, studies that compare successful and unsuccessful attempts and finally studies that compare different elements.

1. Kinematic analysis and description of performing techniques:
   a) Velickovic, Kolar, & Petkovic (2006) investigated the basket with ½ turn to handstand and give their kinematic analysis through four stages (two gravity and two antigravity);
   b) Guo & Jihe (2013) gave a kinematic analysis of the basket to handstand with ½ turn, which was performed by the top Chinese gymnast Teng;
   c) Velickovic et al. (2011) conducted a study with the aim of performing a kinematic analysis and determining the kinematic model of the element. The movement is divided into a gravity phase (fall phase) and antigravity phase;
   d) Yamada & Sato (2013) also worked on the kinematics of the basket to handstand, but they focused on angular momentum. They indicated that moments in the shoulder and hip joint are not correlated with the parameters of the movement speed up, but significantly correlated with the movement speed downward and forward;
   e) Hiley & Yeadon (2012) examined two different ways of performing the actual element. They used three optimization criteria for generating the performed techniques of the basket to handstand and making simulation models: minimizing

the peak moments in the joints, minimizing horizontal velocity before release and maximization of angular momentum.

2. Comparing successful and unsuccessful attempts in order to detect the most important kinematic parameters enables successful execution:
   a) Hiley, Wangler and Predesku (Hiley, Wangler, & Predescu, 2009) worked on the optimization of the basket to handstand through the analysis of successful and unsuccessful attempts. Optimum simulation resulted in improved performance through a combination of increased vertical speed and height of center of gravity of the body in the unsupported phase;
   b) Takei & Dunn (1996), based on the results of their study, indicated the successful performance of the basket to handstand was more likely when withdrawal of the hands is assisted with maximum effort until the center of gravity of the body and torso are found high above the bars to allow the release of bars at a high TT position, the high corner of the body, high vertical speed, horizontal speed backward and angular inertia;
   3) Velickovic et al. (2013) predicted the successful execution of the basket to handstand and as the most important parameters cited the angular velocity of the retroflexors in the shoulder joint, speed of the center of the shoulder joint and angle values in the shoulder joint in first gravity phase, and then based on the speed of the center of gravity of the body (CBG), speed of the shoulder point and angular value in the hip joint in the second gravity and speed of CBG, angle value in the shoulder and hip joint, as well as the angular velocity of anteflexion in the shoulder joint in the third anti-gravity phase.

3. Comparison of different basket to handstand elements:
   a) Takei, Dunn, Nohara, & Kamimura (1995) studied different grips during the execution of this element and give priority to the internal grip.
   b) Velickovic et al. (2005) compared the basket to handstand with the basket to handstand with ½ turn. Taking into account the differences in the first two gravity phases, they propose the basket to handstand as a methodical step in training of the basket to handstand with ½ turn.
   c) Yamada, Nishikawa, Sato, & Sato (2009) compared the baskets to handstand with ½ and full turn around a longitudinal axis, that is, compared different techniques (early and late turns) of performing turns around a longitudinal axis with the above mentioned elements.

For this group of studies we can conclude that the focus of the work was exclusively related to the study of the element Basket to handstand and its variations. The elements cast to support and shot up to handstand on one bar have not been explored yet.

The fifth group – dismounts

This group deals with a wide variety of elements (23 elements in FIG COP), but did not significantly study the selected period (five studies, or less than 25%). Only the back rotation, double tucked somersault and stretched somersault were studied.

Manoni & De Leva (1993a) gave a biomechanical analysis and described the performance of double back somersaults. Gervais et al. (2003) compared good and bad executed dismounts double somersault backward and suggested the best differentiation between good and bad

attempts. Naundorf et al. (2009) examined the elasticity of the bars during the execution of the mentioned dismount and indicated that the typical force-time curve for gymnasts of different performance levels is useful for fault detection of execution.

The stretched backward somersault on two occasions was explored by Prassas (1994; 1998). In the first case, the correlation of kinematic parameters and the evaluation of judges was determined, and in the second case compared it to the front swing, which is realized in the execution of element somersault backward to handstand and dismount stretched somersault backward (already mentioned in the case of the first group).

It is important to note that there is a lack of studies that take into account forward rotation and rotation around the longitudinal axis of the body. Few studies also focused on the dismounts performed passing through a hang.

SYSTEMATIZATION BASED ON THE SAMPLE OF PARTICIPANTS AND ATTEMPTS

The sample of participants in the study ranged from 1 to 16, which indicates the difficulty of collecting a larger sample when trying to process problems of exercises on parallel bars. There are two exceptions when it comes to the sample of participants. In both cases the studies included 53 participants, 53 contestants who took part in the national championships in Japan and in United States, 1995 (Takei et al., 1995) and 53 contestants who took part in the national championships in 1990 (Takei et al., 1996).

Several studies included only one participant, who performed one or more attempts of different elements (Kolar et el., 2002, Velickovic et al., 2005, 2006, 2011, 2013; Wang Yao, & Li, 2009; Guo et al., 2013).

Most of the participants were elite athletes. However, there are studies that dealt with the comparison of elite and average competitors (Prassas & Kelley, 1986; Delignières et al., 1998 Prassas, 2011).

The sample of attempts is very diverse and ranges from 1 to 15 attempts per competitor. The sample of attempts can be systematized in the following way:

1. The sample of participants (one or more gymnasts) perform a single successful attempt of an exercise which is the subject of study (Gervais et al., 2003; Velickovic et al., 2005, 2006; Prassas et al., 2008). These studies were carried out with the aim of providing a kinematic analysis and description of movement.
2. The sample of participants (one or more gymnasts) make a few successful attempts at an element which is the subject of research, which includes most of the research papers (Bolkovic et al., 1995; Takei et al., 1996; Kolar et al., 2002; Prassas et al. 2004; Prassas et al., 2005; Yamada et al., 2009; Hiley et al., 2009; Prassas, 2011; Velickovic et al., 2011, 2013; Hiley et al., 2012). These studies were carried out with the aim of providing a kinematic analysis and description of movement and determining the most important parameters for successful execution.
3. The sample of participants (one or more gymnasts) perform one or more successful and unsuccessful attempts of the same element in order to make comparisons and find errors in the performance technique (Prassas et al., 2004; Velickovic et al., 2013).

SYSTEMATIZATION BASED ON METHODS OF ANALYSIS OF MOVEMENT

The method of kinematic analysis of movement is used in most studies. For further processing of the data, kinematic parameters of movement are taken, as well as goniometric parameters of mutual relations of various body parts, body relations, apparatus and areas. The systems for obtaining kinematic parameters are very different, and the most influential ones are the following:

1. Systems with a non-invasive approach (without using markers): APAS - motion analysis system (Prassas et al, 1994, 1995, 1998, 2004, 2008, 2011; Velickovic et al, 2005, 2006, 2011, 2013); CMAS - system (Bolkovic et al., 1995; Kolar et al., 2002); EMG - elite motion analyzer system (Delignières et al., 1998).
2. Systems with an invasive approach (with the use of markers): EMA - the elite motion analyzer (Delignières et al., 1998); MCS - motion capture system (Hiley et al., 2009).

Plenty of researchers who focused on kinematic parameters, by using the inverse dynamic analysis, also calculated the dynamic parameters (Prassas et al., 1986; Kolar et al., 2002; Linge et al., 2006; Tsuchiya et al., 2001; Yamada et al., 2009). Naundorf et al., (2009) also calculated kinetic parameters from kinematic parameters. Using a synchronized 2D video analysis of movements of bars and gymnasts' performance (2 cameras), they calculated the force based on special calibration.

Cerulli**,** Caraffa, Ragusa, & Pannacci (1998) are the only ones who conducted a study using data obtained from EMG (electromyography) analysis. The subject matter of this study were shoulder injuries. The aim of heir biomechanical study was to make an EMG record of shoulder muscles during exercises on the parallel bars and steel rings and determine possible causes of injury.

Gros et al. (1992), using a special devices for dynamometry, examined the differences between the old and newly constructed bars and they are the only ones who dealt with the problem of parallel bars as apparatus and direct measurement of force. Similar studies have been conducted by Naundorf et al. (2009), but without the use of direct force measurement.

SYSTEMATIZATION BASED ON METHODS OF ANALYSIS OF RESULTS

In terms of these criteria, studies can be systematized as:

1. Studies that only deal with the description of kinematic parameters where the results were obtained in order to determine the model of techniques of analyzed exercises. These studies are the most common ways of explaining the subject matter of the research (over 60% of the recorded works). This group also includes studies which conducted a simple comparison of the obtained results between:
   a) the same kinematic parameters, of different gymnasts who perform the same element (most common),
   b) the same kinematic parameters, of different gymnasts who perform different elements (fewer studies than in the previous group).
2. Statistical procedures, as an aid in solving research problems and the formulation of final conclusions are not frequently represented in studies of exercises on parallel bars. The most commonly used procedures are the correlation analysis and analysis of differences:

a) Correlation analysis:
   - Pearson's correlation coefficient:
     - Used to determine the relation between kinematic parameters and judges' evaluation (Prassas, 1994);
     - Used to determine the relationship between the same kinematic parameters of gymnasts who perform similar elements (Kolar et al., 2002);
     - Used to determine connections between the different kinematic parameters of the same element (Yamada et al., 2013).

b) Statistical significance of differences of arithmetic means:
   - T – test:
     - For differences in kinematic parameters between successful and unsuccessful attempts (Prassas, 1994; Takei et al., 1996);
     - For differences in kinematic parameters between two similar elements (Prassas et al., 1998; Tsuchiya et al., 2001);
   - Nonparametric tests:
     - For differences in kinematic parameters between two similar elements (Man-Whitney test – Prassas, 2011);
     - For differences in kinematic parameters between successful and unsuccessful attempts (Median test – Gervais et al., 2003).

c) Regression analysis:
   - The influence of a selected set of kinematic parameters on the efficiency of execution estimated by judges' evaluation (Prassas et al., 2008);
   - Determination of kinematic parameters that have the highest influence on the successful performance of an element (Velickovic et al, 2013).

CONCLUSION

Research papers that deal with exercises on the parallel bars mainly use kinematic methods of analysis of movement. Methods which calculate dynamic parameters are used to a substantially lesser extent . In the COP for judging, as many as 168 elements are shown, which are performed and which can be performed at competitions, on the parallel bars. Only 22 elements were investigated (based on the collected works) out of 168 elements. This only points to the fact that studies on exercises on parallel bars, even if conducted over a long period, are still in their infancy.

Considering the great prospect of elements and the ability of upgrading, it is necessary to start with the research of elements which are performed through support on the upper arms (second group), since there is no research that examines this group of elements.

REFERENCES

Bolkovic, T., & Cuk, I. (1995): *Comparison of some elements through long hang swing forward on parallel bars.* Univerza v Ljubljani, Fakultet za sport, Ljubljana.

Cerulli, G., Caraffa, A., Ragusa, F., & Pannacci, M. (1998). A biomechanical study of shoulder pain in elite gymnasts. In H.J. Riehle & M.M. Vieten (Eds), *16 International Symposium on Biomechanics in Sports* (pp. 308-310). Konstanz – Germany.

Delignières, D., Nourrit, D., & Micaleff, J. P. (1998). Preferred Coordination Modes in the First Steps of the Learning of a Complex Gymnastics Skill. *Human Movement Science*, 17(2), 221-241.

Gervais, P., & Dunn, J.H. (2003). The double back somersault dismount from the parallel bars. *Sports Biomechanics*, 2(1), 85-101.

Gros, H.J., Leikov, H., & Heisel, W. (1992): Biomechanical considerations for a new design of the parallel bars. In R., Rodano, G., Ferrigno & G. C. Santambrogio (Eds), 10 *International Symposium on Biomechanics in Sports* (pp 273-276). Milan – Italy.

Guo, E., & Jihe, Z. (2013). Kinematic analysis of basket with 1/2 turn to handstand of Xaibin Teng on parallel bars. In T. Y. Shiang, W. H. Ho, P. C. Huang & C. L. Tsai (Eds), 31 *International Conference on Biomechanics in Sports*. Taipei, Taiwan.

Hiley, M. J., Wangler, R., & Predescu, G. (2009). Optimization of the Felge on Parallel Bars. *Sports Biomechanics*, 8(1), 39-51.

Hiley, M. J., & Yeadon, M. R. (2012). The Effect of Cost Function on Optimum Technique of the Undersomersault on Parallel Bars. *Journal of Applied Biomechanics*, 28, 10-19.

International Gymnastics Federation – FIG. (2017). *2017 Code of points men's artistic gymnastics*.

Kolar, E., Andlovic K., & Stuhec, S. (2002): Comparative analysis of selected biomechanic characteristics between a support backward swing and support swing for the 1¼ straddle-piked forward somersault on the parallel bars. *Sports Biomechanics*, 1(1), 68-78.

Linge, S., Hallingstad, O., & Solberg, F. (2006). Modelling the parallel bars in Men's Artistic Gymnastics. *Human Movement Science*, 25(2), 221-237.

Manoni, A., & De Leva, P. (1993b). Comparative biomechanical analysis of three different forward somersaults at the parallel bars. In G. P. Brueggmann & J. K. Ruhl (Eds.), *Biomechanics in gymnastics*, Conference proceedings (pp. 487-498). Koln: Strauss.

Manoni, A., & De Leva, P. (1993a). Biomechanical analysis of a double backward somersault at the parallel bars. In G.-P. Brueggmann & J. K. Ruhl (Eds.), *Biomechanics in gymnastics, Conference proceedings* (pp. 475-486). Koln: Strauss.

Naundorf, F., Knoll, K., & Brehmer, B. (2009). Calculation forces from bar movement on parallel bars in gymnastics. In A. J. Harrison, R. Anderson, I. Kenny (Eds), 27 *International Conference on Biomechanics in Sports*. Limerick, Ireland.

Popov, D. (1989). *The kinematic model of post active transmission of kinetic energy in support and under support on parallel bars.* Unpublished doctoral dissertation, Belgrade: Faculty of Physical Education.

Prassas, S., & Papadopoulos, C. (1998). Dynamics of forward swing skills on the parallel bars. In H.J. Riehle & M.M. Vieten (Eds), *16 International Symposium on Biomechanics in Sports* (pp 216-218). Konstanz: Germany.

Prassas, S. (1994): Technique analysis of the back toss on the parallel bars performed by elite gymnasts. In A. Barabás & Gy. Fábián (Ed), *Biomechanics in Sports XII*, ISBS (pp 249-251), Budapest, Hungary.

Prassas, S. (1995). Technique analysis of the 1992 compulsory dismount from the parallet bars. In T. Bauer (Ed), *13 International Symposium on Biomechanics in Sports* (pp 160-163), Thunder Bay, Ontario, Canada.

Prassas, S. (1999). Biomechanical research in gymnastics: What is done, what is needed. *Applied Proceedings of the XVII International Symposium on Biomechanics in Sports*: Acrobatics, 1-10.

Prassas, S. (2011). Comparative study of giant swings on the parallel bars. In J. Paulo Vilas-Boas et all (Eds), *29 International Conference on Biomechanics in Sports* (pp 367-368). Porto, Portugal.

Prassas, S. G., & Kelley, D. L. (1986). Shoulder Joint Torques and the Straight Arm/Flexed Hips Press Handstand on the Parallel Bars. In J. Terauds, B. A. Gowitzke & L. E. Holt (Eds), *4th International symposium, Biomechanics in sports* (pp. 83-95). Halifax, Canada.

Prassas, S., Ariel, G., & Ostarello, J. (2008). Score prediction on kips performed on the parallel bars. *26 International Conference on Biomechanics in Sports* (pp 638). Seoul, Korea.

Prassas, S., Kwon, Y. H., & Sands, W. A. (2006). Biomechanical research in artistic gymnastics: a review. *Sports Biomechanics*, 5 (2), 261-291.

Prassas, S., Ostarello, J., & Inouye, C. (2004). Giant swings on the parallel bars: a case study. In M. Lamontagne, D. Gordon E. Robertson, H. Sveistrup (Ed), *22 International Symposium on Biomechanics in Sports* (pp 133). Ottawa, Canada.

Prassas, S., & Ariel, G. (2005). Kinematics of giant swings on the parallel bars. In Q. Wang (Ed), *23 International Symposium on Biomechanics in Sports* (pp 953-955). Beijing: China.

Takei, Y., & Dunn, J. H. (1996). A comparison of techniques used by elite gymnasts in performing the basket-to-handstand mount. *Journal of Sports Sciences*, 14 (3), 269-279.

Takei, Y., Dunn, J., Nohara, H., & Kamimura, M. (1995): New outer grip technique used by elite gymnasts in performing the feldge to handstand mount. *Journal of Applied Biomechanics*, 11(2), 188-204.

Tsuchiya, J., Murata, K., & Fukunaga, T. (2001). Kinetic Analysis of Backward Giant Swing on Parallel Bars. *International Journal of Sport and Health Science*, 2, 211-221.

Velickovic, S., Kolar, E., & Petkovic, D. (2006). The kinematic model of the basket with ½ turn to handstand on the parallel bars. *Facta Universitatis, Series: Physical Education and Sport*, 4 (2), 137 - 152.

Velickovic, S., Kolar, E., Kugovnik, O., Madic, D., Aleksic-Veljkovic A., & Paunovic M. (2013). Prediction of the success of the basket to handstand on parallel bars based on kinematic parameters: A case study. *Facta universitatis - series: Physical Education and Sport*, 11 (1), 9-21.

Velickovic, S., Kolar, E., Kugovnik, O., Petkovic, D., Petkovic, E., Bubanj, S., Bubanj, R., & Stankovic, R. (2011). The kinematic model of the basket to handstand on the parallel bars. *Facta universitatis - series: Physical Education and Sport*, 9 (1): 55-68.

Velickovic, S., Kugovnik, O., Kolar, E., Bubanj, R., Madic, D., & Supej, M. (2005). Comparison of some kinematic variables between basket and basket with ½ turn to handstand on the parallel bars. *Sport*, 53 (1), 63-69.

Wang, X-D., Yao, X-M., & Li, W. (2009). A Kinematic Analysis of Teng Haibin' s Backward Giant Swing with twist 360° on Parallel Bars. *Journal of Beijing Sport University*, 1: 116-117.

Yamada, T., & Sato, Y. (2013). Characteristics of joint torques in performing the basket to handstand on parallel bars. In T-Y. Shiang, W-H. Ho, PC. Huang, C-L. Tsai (Eds), *31 International Conference on Biomechanics in Sports*. Taipei, Taiwan.

Yamada, T., Nishikawa, D., Sato, Y., & Sato, M. (2009). Comparison of turn techniques in performing the basket with half turn to handstand on parallel bars. In A. J. Harrison, R. Anderson, I. Kenny (Eds), *27 International Conference on Biomechanics in Sports*. Limerick, Ireland.

SISTEMATIZACIJA DOSADAŠNJIH ISTRAŽIVANJA VEŽBI NA RAZBOJU

Razboj je jedna od šest sprava muškog gimnastičkog višeboja, i imajući u vidu veliku raznovrsnost elemenata na ovoj spravi, kao i stilova izvođenja i načina njihove obuke, postoji i veliki dijapazon istraživanja koja su sprovedena a vezana su za ovu spravu i vežbanje na ovoj spravi. Cilj ovog rada su dosadašnja istraživanja vežbi na razboju i sistematizacija istraživačkih radova vezanih za vežbanje na razboju. U Pravilniku za ocenjivanje prikazano je čak 168 elemenata (FIG, 2015) koji se izvode i koji se smeju izvoditi na takmičenjima na razboju. Od tog broja istraženo je samo 22 elementa (13.5%) a uglavnom su istraživanja vezana za analizu tehnike izvođenja pomenutih elemenata. Nema istraživanja koja se bave metodskim postupkom dolaska do idealnog izvođenja nekog elementa. Činjenica je da su istraživanja vežbi na razboju, i ako sprovođena u dugom vremenskom periodu, još na početku. Imajući u vidu veliku perspektivnost elementa i mogućnost nadgradnje, neophodno je započeti sa istraživanjima elemenata koji se izvode kroz potpor na nadlakticama.

Ključne reči: *sportska gimnastika, razboj, sistematizacija.*