THE ANALYSIS OF THE INFLUENCE OF TEACHNING METHODS ON THE ACQUISITION OF THE LANDING PHASE IN FORWARD HANDSPRING

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Abstract

Forward handspring is an acrobatic element that has been used in competitive gymnastics for many years as one of the basic elements combined with other acrobatic elements with forward rotation of the body. A whole series of quality descriptions of its execution technique can be found in recent literature. Still, scientific research based on the analysis of kinematical and kinetic components, that is, on biomechanical characteristics of its execution are rare. By using the hierarchical cluster analysis and on the basis of relevant kinematical parameters the inter-relationship between teaching methods and acquisition of landing in the forward handspring was analysed. The obtained results show that the teaching methods of the landing phase in forward handspring are highly correlated, and they concur in most of the analysed kinematical parameters. The homogenization of groups and their similarity were achieved on the basis of similar values of parameters determining the technical component of the landing phase execution in forward handspring and relating to the angles between certain body segments.

Key words: *artistic gymnastics, forward handspring, landing phase, biomechanics, cluster analysis, teaching methods*

INTRODUCTION

Artistic gymnastics, as one of the so called conventional sports, prescribes the whole series of rules by the Code of Points (Fédération Internationale de Gymnastique, 2006). It is a specific and a highly demanding sports branch. The complexity of this sport is evidenced in that male gymnasts participate in six and female gymnasts in four events in which, with the exception of vault, they perform gymnastics routines. These routines are comprised of the whole series of simple and complex gymnastics elements that are interconnected into a whole. Today there are hundreds of gymnastics elements and combinations (Brüggemann, 1994; Prassas, 2006), and their number continuously increases. This multitude of elements has been classified into structural groups defined according to some common principles on basis of which the elements are executed. As for judging, the advantages ofartistic gymnastics lie in the fact that it has accurately defined rules on basis of which technical and aesthetic components of execution of each element and routine are scored. According to the prescribed rules, the assessment of quality is done taking into account three factors, and the efficiency of execution depends on their interaction – the trajectory of the movement of the centre of gravity (CG) defining the technical components, trajectories between certain segments of the body and the space-time co-ordinateness of kinematical indices during execution that define both the aesthetic and the functional component.

In the execution of routines that end with dismounts from an apparatus as well as in vaults and acrobatic elements and links both on the balance beam and on the floor one of the dominant final phases of routine execution is the landing phase. It commences with the first contact of feet with the surface and ends with a steady balance stance. The Code of Points strictly penalizes (from .10 – 1.00 points) even the smallest unsteadiness at landing (lunge, hop or fall) which can affect the ranking of the gymnast. That is the reason why the landing phase is considered to be significant in the assessment of the quality of execution of gymnastics elements.

The basic objective of landing is to effectively reduce the performer's linear and rotary motions to zero immediately upon establishing contact with the ground. Although this may appear to be a relatively simple task to master, in practice it is often very difficult. This is because the very nature of any landing phase is contingent on all that has occurred before it. Seemingly minor inaccuracies in the earlier phases of the skill can often add up to produce major difficulties in the landing phase. In fact, consistent poor control in the landing phase of a skill is usually a very good indicator that the real problem lies with one or more of its preceding phases – take-off phase, repulsion phase, or both (McNitt-Gray et al., 2005; Lilley et al., 2007). Biomechanical analyses in artistic gymnastics are numerous, however, the assessment of quality of execution of gymnastics elements is principally based on defining the technique (Arampatzis and Brüggemann, 1998), on the comparison of various techniques (Franks, 1993; Knoll, 1996; Yoshiaki et al., 2003), on identification of errors in execution (Nakamura et al., 1999), on defining biomechanical characteristics of gymnastics apparatus (Daly et al., 2001), on identification and prevention of injuries (Taunton et al., 1988; Sands, 2000; Self and Paine, 2001) as well as on quick feedback. The training process in artistic gymnastics primarily implies the acquisition of gymnastics elements and it is based on accurate and directed training by applying a series of preparatory and specific teaching methods. Biomechanical research dealing with this issue is rare (Čuk, 1995; Živčić, 2000) regardless of the fact that it could enable quick and successful interaction between the coach and the gymnast as well as a quicker progress, which is the basic goal of the training process in artistic gymnastics. Therefore, the goal of this research was to identify, by means of the hierarchical cluster analysis, the relationship between teaching methods and the acquisition of the landing phase in the forward handspring on the basis of relevant kinematical parameters.

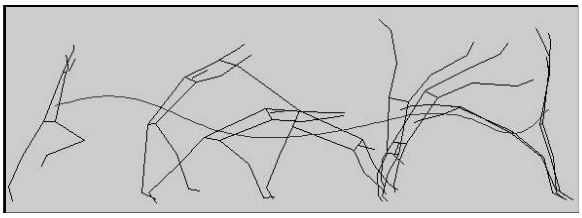
METHODS

For this research the basic acrobatic element – forward handspring – was selected and the accompanying teaching methods applied for the acquisition of the landing phase. The demonstration of the analysed elements was done by a top-level gymnast, a multiple Croatian champion and a competitor at European and World Championships as well as at the Olympic Games in Atlanta in the year 1996. As an elite gymnastics competitor, the subject fitted the model of top-level gymnasts in the world according to his anthropometric characteristics (body height: 161 cm; body weight: 59 kg).

The recording of video material was done by two VHS video cameras, at the speed of 60 frames per second. Each teaching method was recorded in the same way at the moment of contact of feet with the surface, the cameras being positioned at 45° angles to the axis perpendicular to the direction of the subject's motion and passing through the vertical of the landing spot. The camera's lenses were at the subject's hip height. All movements were done in the same direction. Data processing was done according to the standards of the APAS (Ariel Performance Analysis System, 1995) procedure. It was done in classical phases imposed by the procedure itself – digitalization of the video recording and the referential points on the body, transformation into the 3D space, filtering of data and the calculation of kinematical values. Six forward handspring teaching methods that can be regarded as the most convenient for the teaching of the landing phase were analysed (Figure 1): drawing the co-gymnast over the back through the bridge (BRIDGE), under swing dismount from parallel bars (UNSWIN), forward handspring from the lunge and from a higher surface (FHLHS), forward handspring from the hop and from ahigher surface (FHHHS), forward handspring from the push-off from the take-off board (FHPBS) and forward handspring from the push-off from the mat (FHPOM). To analyse and compare the landing phase teaching methods with the actual landing phase in the forward handspring, the kinematical variables characteristic for this phase of the execution were selected (Table 1).

The testing of biomechanical justification of the analysed teaching methods that are intended for the teaching of the landing phase in forward handspring was done by using the hierarchical cluster analysis (Ward's method on the basis of Euclidean distances, 1963). The obtained results are presented by dendrograms

FORWARD HANDSPRING (FWHSP)



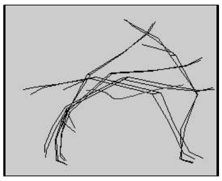
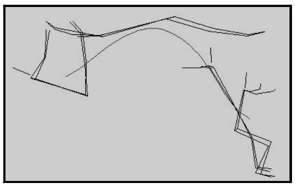
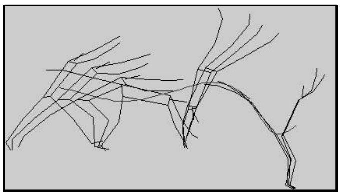
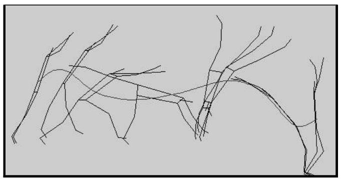
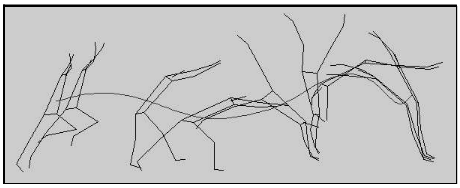
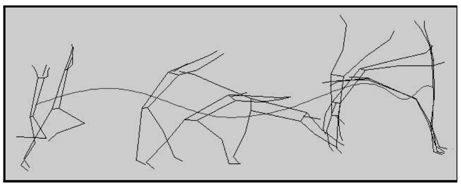
NAME OF THE TEACHING METHOD	THE KINOGRAM OF THE TEACHING METHOD
1 Drawing the co-gymnast over the back through the bridge (BRIDGE)	
2 Under swing dismount from parallel bars (UNSWIN)	
3 Forward handspring from the lunge and from a higher surface (FHLHS)	
4 Forward handspring from the hop and from a higher surface (FHHHS)	
5 Forward handspring from the push-off from the take-off board (FHPBS)	
6 Forward handspring from the push-off from the mat (FHPOM)	

Figure 1. *Kinograms of the forward handspring and of the methods for teaching the landing phase*

Table 1. *Kinematical parameters in the landing phase of the forward handspring*

KINEMATICAL PARAMETERS		ABBREVIATION	MEASURE
1	Height of the CG in the landing phase	CGYLEND	m
2	Angle of the CG in the landing phase	ACGLEND	degree
3	Knee angle in the landing phase	AKLEND	degree
4	Hip angle in the landing phase	AHLEND	degree
5	Shoulder angle in the landing phase	ASLEND	degree
6	Vertical velocity of the CG in the landing phase	VCGYLEND	m/s
7	Horizontal velocity of the CG in the landing phase	VCGXLEND	m/s

CG – centre of gravity

that show the whole process of the hierarchical tree clustering of teaching methods and the level at which the subject has joined the cluster. The results, as well as their graphical presentation, were processed by using the statistical package Statistica 5.0 for Windows

RESULTS

In the process of teaching the landing phase six teaching methods can be identified (Figure 1). On the basis of extracted kinematical parameters at the moment of the first contact of feet with the surface (Tables 2 and 3) the . correlation matrix (Table 4) makes it possible to notice significant correlations between the teaching methods and the final movement structure. The variables FHPOM (.98) and FHPBS (.97) had the highest statistically significant correlation ($p<.05$) with the forward handspring, whereas the variables FHHHS and UNSWIN (.96) as well as FHLHS (.94) had somewhat lower correlations. The variable BRIDGE had the lowest but still statistically significant correlation (.88) with the movement structure.

Table 2. *Kinematical variables of the forward handspring and the methods of teaching the landing phase*

phase

KINEMATICAL VARIABLES	FWHSP	UNSWIN	FHLHS	FHHHS	FHPBS	FHPOM	BRIDGE
CG height in the landing phase (cm)	75	75	92	92	83	77	74
CG A in the landing phase (degrees)	45	60	65	68	47	43	44
Shoulder A in the landing phase (degrees)	201	203	197	189	187	209	211
Knee A in the landing phase (degrees)	143	157	147	151	180	171	175
Hip A in the landing phase (degrees)	190	173	180	188	220	222	227

CG – centre of gravity

Table 3. *Horizontal and vertical velocities of the forward handspring and of methods for teaching the landing phase*

HORIZONTAL AND VERTICAL VELOCITIES (cm/sec)	FWHSP		UNSWIN		FHLHS		FHHHS		FHPBS		FHPOM		BRIDGE	
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
velocity of the CG	198	-97	144	-265	117	-182	171	-205	150	-200	137	-122	68	25

CM – centre of gravity

Table 4. *Correlation matrix of kinematical parameters of the forward handspring and of the teaching methods of the landing phase*

	FWHSP	BRIDGE	UNSWIN	FHLHS	FHHHS	FHPBS	FHPOM
FWHSP	1.00	.88*	.96*	.94*	.96*	.97*	.98*
BRIDGE		1.00	.83*	.79*	.86*	.88*	.94*
UNSWIN			1.00	1.00*	.97**	.95*	.94*
FHLHS				1.00	.97*	.94*	.92*
FHHHS					1.00	.99*	.97*
FHPBS						1.00	.99*
FHPOM							1.00

Significant at p <.05; N=7

The highest correlation (1.00) in the landing phase was obtained between the variables FHLHS and UNSWIN, and the correlation of .99 was obtained between the variables FHPBS and FHHHS on the one hand, and the variables FHPBS and FHPOM on the other.

The hierarchical cluster analysis made it possible to identify both the differences between certain teaching methods used to teach the landing phase in the forward handspring and their interrelationship with the actual movement structure for whose teaching they are intended.

The analysis based on the values of spatial parameters (Figure 2) yielded two homogeneous groups of elements. The shortest distance was to be observed between the variable FWHSP and FHHHS. This group was also made up of the variable FHHHS and, at a somewhat larger distance, the variable UNSWIN. The greatest similarity between elements belonging to this group is evidenced in the hip angulation degrees (173^0 -190^0), knee angle degrees (143^0 – 157^0)as well as shoulder degrees (189^0 – 203^0) in the first contact of feet with the surface. Greater similarities were evident between the variables UNSWIN, FHHHS and FHLHS in the angle between the body's centre of gravity and the surface (60^0 – 68^0), and between the variables FHLHS and FHHHS in the height of the body's centre of gravity at the moment of landing (92 cm).

The second group found to exist at the second shortest distance was comprised of the variables FHPOM, BRIDGE and FHPBS. This group of elements was characterized by similar values in spatial parameters that related to the angle between the centre of gravity (CG) and the surface at the moment of landing (43^0 – 47^0) as well as to the knee angle (171^0 – 180^0) and hip angle (220^0 -227^0) at the moment of the first contact of feet with the surface.

HSP was at the approximately same distance with the second group of elements, and the reasons for this can be sought in the almost identical values in parameters that relate to theheight (74 - 77cm) and the angle of the body's centre of gravity (43^0 – 47^0) at themoment of the first contact of feet with the

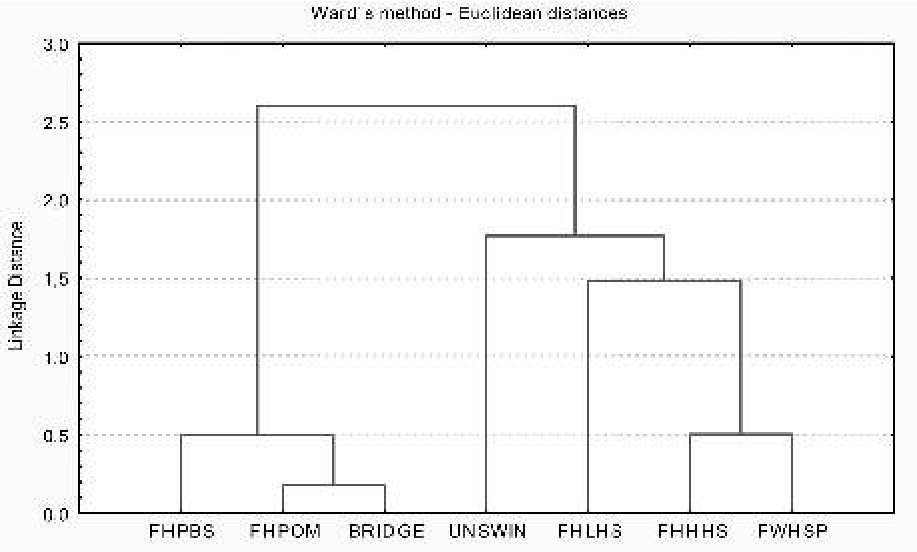


Figure 2. *Dendrogram of the hierarchical clustering of elements in the landing phase on the basis of spatial parameters*

surface at landing.

With regard to the final movement structure, the hierarchical cluster analysis of time parameters of certain teaching methods and their distances yielded a somewhat different cluster distribution than the one described for the spatial parameters. Two heterogeneous groups with larger distances were obtained (Figure 3). The variable FHPOM, which at the same time had the most similar values of the horizontal and vertical velocity of the body's centre of gravity at the moment of the contact of feet with the surface – horizontal velocity: 198, 137 cm/s; vertical velocity: -97, -122 cm/s – was found to be at the shortest distance from the forward handspring.

As regards the horizontal (117 – 171 cm/s) and the vertical velocity (-182 – (-)205 cm/s), the variables FHLHS, FHHHS and FHPBS were the most similar to these elements. Larger differences were to be noticed in the variable UNSWIN in vertical velocity (-256 cm/s) and in the variable BRIDGE both in the horizontal and in the vertical velocity (68 and 25 cm/s) of the body's centre of gravity at the moment of the first contact of feet with the surface at landing.

DISCUSSION

The landing phase commences with the first contact of feet with the surface in which the surface in which horizontal velocity is abruptly reduced to zero (final position). This phase is said to have been successfully accomplished if the body is maximally extended and the arms fully extended above and behind the head before the first contact of feet with the surface. Also, amortization occurs after the first contact of feet with the surface and it is manifested in the decrease of knee and hip angles and followed by an upright body position with arms fully extended above the head (final position) (George, 1980). All errors from previous parts of the element execution are accumulated in this phase – namely, the low height of the body's centre of gravity as well as low values of knees, hips and shoulders angles are an accurate indicator of the occurrence of one or more errors made during the execution of previous phases of the forward handspring on the one hand, and of the poor landing phase on the other (Živčić, 2000).

Taking into account the basic biomechanical characteristics of the landing phase as well as the conducted analyses, it is obvious that at the moment of the first contact of feet with the surface in the forward handspring there are similarities in spatial parameters, i.e. the number of degrees between certain body segments (upper arm and the trunk, upper leg and the trunk, upper and the lower leg) in most teaching methods. Since the quality of the landing phase execution is characterized by the appropriate body position, it can be noticed that in this sense

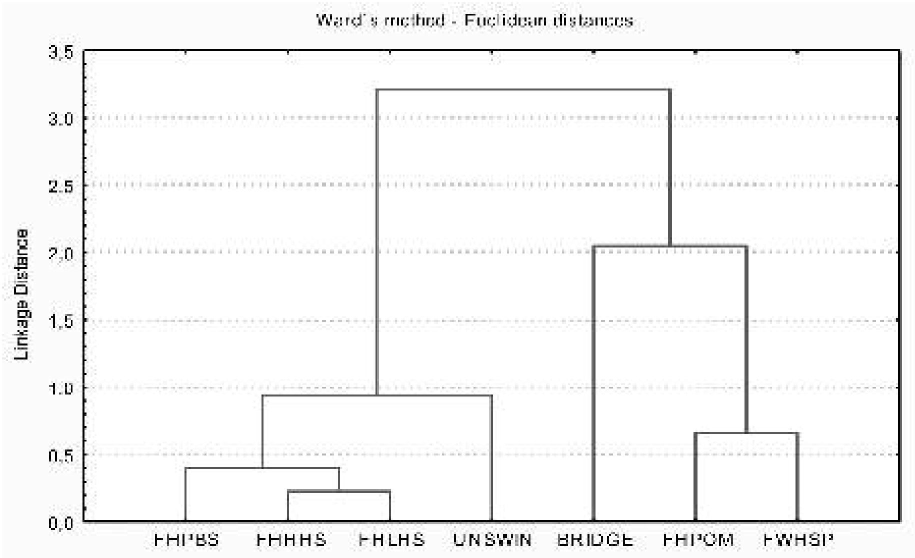


Figure 3. *Dendrogram of the hierarchical clustering of elements in the landing phase on the basis of time parameters*

most teaching methods meet the basic requirements of the prescribed technique.

The analyses also made it possible to become aware that the teaching methods that are not executed from a higher surface, meaning that they are executed in conditions more similar to the ones in the final technique, have similar values of the angle as well as of the height of the body's centre of gravity at the moment of the first contact of feet with the surface. The elements executed from a higher surface clearly have different characteristics of the flight trajectory which was evidenced in higher values obtained in the given parameters.

The analysis of time parameters that relate to the velocities of the body's centre of gravity at the moment of landing showed that the teaching methods that are executed from a higher surface had more similar values of horizontal velocities of the body's centre of gravity with the velocities in the final movement structure. The vertical velocities, however, were two to three times higher with the teaching methods of the forward handspring.

The teaching method BRIDGE had the greatest similarity with the forward handspring in spatial parameters, particularly as regards the angle and the height of the body's centre of gravity as well as the angle between the upper arm and the trunk. This exercise was directed towards the realization of accurate body positions which was manifested by the values of spatial parameters.

CONCLUSION

The forward handspring is an acrobatic element that has been used in competitive gymnastics for many years as one of the basic elements combined with other acrobatic elements with forward rotation of the body. Its technical excellence has been thoroughly described by several authors (Spilthoorn 1973; Hebbelinck and Borms 1975; Waren 1977; George 1980; Hay, 1985), whereas the scientific research dealing with kinematical and kinetic components, i.e. biomechanical characteristics of execution, are very rare compared to other gymnastics elements (Forwood et al., 1985).

That is the reason why, in this research, it was difficult to compare the obtained results with the results of other analyses. The whole series of biomechanical analyses of the forward handspring was done by Živčić that were, on the basis of kinematical description of the forward handspring technique (Živčić et al., 1996), directed towards the identification of errors in execution (Živčić et al., 1997), the comparison of various execution techniques (Živčić et al., 1999), the identification of interrelationship between the teaching methods and the forward handspring (Živčić, 2000) as well as the defining of the key kinematical parameters of the push-off phase (Živčić et al., 2007). This research shows one way of diagnosing and scientific verification of methods of teaching of a gymnastics element by means of biomechanical analysis (Živčić et al., 2008).

The results obtained in this research show that the methods of teaching the landing phase in forward handspring are highly correlated and that they concur in most kinematical parameters that were taken into account. Similarities have been noticed with the parameters relating to angles between certain segments of the body, in particular the angle between the upper and lower leg, upper leg and the trunk as well as the trunk and the upper arm. These parameters define the accuracy of positions determining the technical component of the landing phase execution in the forward handspring (Živčić et al., 1999). This is the reason that makes it possible to conclude that the homogenization of groups was the result of these parameters. Likewise it is worth mentioning that the height and the angles of the body's centre of gravity at the moment of the first contact of feet with the surface differed from element to element which was probably caused by different conditions in which they were executed (from a higher surface, onto a higher surface – mat, over the other gymnast's back, from parallel bars). The selected teaching methods belong to the synthetic teaching/learning method which implies the execution of the whole final element in somewhat easier conditions. In each teaching method the element was executed with the same trajectories, however, not at the same velocities because each method is concentrated on the accuracy of certain body positions during execution. The basic intent of different teaching methods is to acquire the given element quickly and efficiently in order to discover any possible errors in execution in time and in order to correct them. This is the reason why the clustering of elements referring to horizontal and vertical velocities of the centre of gravity at the first contact of feet with the surface varied. Greater similarities were to be seen mainly in horizontal velocities, and the teaching method FHPOM had the largest similarity with the forward handspring.

The analysis of kinematical parameters encompassed the moment of the first contact with the surface and not the entire landing phase, so that the phase of amortization and stabilization is lacking. One of the reasons for this was that the forward handspring is primarily the linking element followed by another acrobatic element whereupon the landing type depends. If it were considered as a separate technical element, it would be more connected with school sport in which forward handspring is taught as a separate, highly complex and demanding acrobatic element. Likewise, in various teaching methods the landing surface (soft) differently affects the amortization phase and the establishing of the balance stance.

Finally, it should be mentioned on the basis of previous analyses that the selection of certain teaching methods cannot be explicitly defined. This selection of a teaching method and the efficiency of element acquisition continue to depend on the knowledge and experience of gymnastics experts. The reason for this is manifold and it primarily relates to the duration of the teaching/learning process, conditions in which this process develops, the basic and the specific physical conditioning of gymnasts, the basic motor knowledge of the gymnast prior to the teaching of a new element, and the whole series of other psychological and economical prerequisites that depend on the goals and types of the training process (competitive gymnastics, school sport). Since biomechanical research is one of the foundation stones of the programming and control of the training process, the results of this analysis may contribute to a more objective teaching/learning process of gymnastics-related movement structures. They are not exclusively directed towards the selected technical element, i.e. their contribution is oriented both towards scientific verification of teaching methods for the acquisition of all gymnastics elements and towards sports in which the teaching approach is dominant for the technical quality of execution, and thus consequently for the success. The application of such analyses is possible and recommended with selective categories in which systematic and timely successive application could determine any possible incorrect approach regarding the teaching methods of the basic gymnastics elements that operate as the basis for further development and acquisition of more complex as well as very demanding elements.

REFERENCES

Arampatzis, A., and Brüeggmann, G.-P. (1998). A mathematical high bar-human body model for analysing and interpreting mechanical-energetic processes on the high bar. Journal of Biomechanics, 3: 1083-1092.

Brüggemann, G.P. (1994a). Biomechanics of gymnastic techniques. Sport Science Review, 3(2): 79-120.

Čuk, I. (1995). Razvoj in analiza nove gimnastičke prvine (seskok podmet – seskok podmetno salto naprej z bradlje). (Dissertation). Ljubljana: Fakulteta za šport Univerza v Ljubljani.

Daly, R.M., Bass, S.L. and Finch, C.F. (2001). Balancing the risk of injury to gymnastics: how effective are the counter measures? British Journal of Sports Medicine, 35(1): 8-19.

Fédération Internationale de Gymnastique. (2006). Code of points for Women's Artistic Gymnastics. Moutier: Fédération Internationale de Gymnastique.

Franks, I. M. (1993). The effects of experience on the detection and location of performance differences in a gymnastic technique. Research Quarterly for Exercise and Sport, 64(2): 227-231.

Forwood, M. R., Clarke, D., and Wilson, B. D. (1985). A cinematographic analysis of the front handspring to front somersault. The Australian Journal of Science and Medicine in Sport, 3, 8-14.

George, S .G. (1980). Biomechanics of women's gymnastics. Englewood Cliffs: Prentice-Hall, Inc.

Hay, J.G. (1985). The biomechanics of sport techniques. Englewood Cliffs, NJ: Prentice Hall.

Hebbelinck, M., and Borms, J. (1975). Cinematographic and electromyographic study of the front handspring. In M. Hebbelinck and J. Wartenweiler (Eds). Biomechanics I. University Park Press. Karascony I., and Čuk, I. (2005). Floor exercises, methods, ideas, curiosities, history. ŠTD Sangvinčki, Ljubljana, Slovenija.

Knoll, K. (1996). Analysis of acrobatic tumbling exercises on floor and balance beam. In J. Abrantes (Ed.) Proceedings of XIV International Symposium on Biomechanics in Sport (325-328). Universidade Tecnica de Lisboa, Lisboa, Portugal.

Lilley, E.S., Bradshaw, E.J., and Rice, V.J. (2007). Is jumping and landing technique symmetrical in female gymnasts. In XXXV ISBS Symposium 2007, Ouro Preto, Brasil.

McNitt-Gray, J., Racquejo, P., Costa, K., and W. Mathiyakomo (2005). Landing success rate during the artistic gymnastics competition of the 2000 Olympic Games: Implications for improved gymnastics/ Mat interaction. www.coachesinfo.com (online 25.07.2009)

Nakamura, T., Kato, S., and Watanabe, Y. (1999). A case study on the forward handspring of beginning gymnasts. In Bulletin of Institute of Health and Sports Sciences, University of Tsukuba. 22(1), 33-42.

Nelson, C., and Zatsiorsky, V. (1994) Sport biomechanics: Current perspectives. Sport Science Review, 3(2): 1-7.

Prassa, S. (2006). Biomechanical research in gymnastics: What is done, what is needed. www.coachesinfo.com (online 25.07.2009)

Prassa, S., Known, Y.-H., and Sands, W.A. (2006). Biomechanical research in artistic gymnastics: A review. Sports Biomechanics, 5(2): 261-291.

Sands, W.A. (2000). Injury prevention in women's gymnastics. Sports Medicine, 30(5), 359-373. Self, B.P., and Paine, D. (2001). Ankle biomechanics during four landing techniques. Medicine Science Exercises. 33(8): 1138-1144.

Spilthoorn, D. (1973). The single foot take-off for tumbling exercises. Modern Gymnast, 6/7, 34-37.

Taunton, J.E., McKenzie, D.C., and Clement, D.B. (1988). The role of biomechanics in the epidemiology of injuries. Sports Medicine. 6(2): 107-120.

Yoshiaki, T., Dunn, J.H., and Blucker, E. (2003). Techniques used in high–scoring and low–scoring “Roche” vaults performed by elite male gymnasts. Sports Biomechanics, 2(2): 141-162.

Živčić, K., Šadura, T., and Dragičević, S. (1996). Kinematička deskripcija osnovne tehnike premeta naprijed. In D. Milanović (Ed.) Proceedings of the 3rd Alps-Adriatic Conference on Sport - “Dijagnostika u sportu” (161-165). Zagreb: Fakultet za fizičku kulturu Sveučilišta u Zagrebu.

Živčić, K., Hraski, Ž.., and Šadura, T. (1997). Detekcija karakterističnih grešaka rane faze učenjapremeta naprijed. Hrvatski športskomedicinski vjesnik. 12(1): 25-32.

Živčić, K., Hraski, Ž., and Šadura, T. (1999). Usporedba dva načina izvedbe premeta naprijed. In D. Milanović (Ed.) Proceedings of the 2nd International Scientific Conference on Kinesiology, Dubrovnik, (pp. 244-247). Zagreb: Fakultet za fizičku kulturu.

Živčić, K. (2000). Biomehaničko vrednovanje vježbi za izvedbu premeta naprijed. (Dissertation). Zagreb: Kineziološki fakultet

Sveučilišta u Zagrebu.

Živčić, K., Breslauer, N., Stibilj – Batinić, T. (2008). Dijagnosticiranje i znanstveno verificiranje metodičkog postupka učenja u sportskoj gimnastici. Odgojne znanosti, 1(15): 159-180.

Waren, M. (1977). Basic gymnastics for women: the front handspring. International Gymnastics, 7, 55.

Winter, D. (1979). Biomechanics of human movement. USA: John Wiley and Sons, Inc.