LANDING ERRORS IN MEN'S FLOOR EXERCISE

Miha Marinšek, Iva Čuk*

Faculty of Education, University of Primorska, Maribor, Slovenia
**Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia*

Submitted in April, 2008

In our research we focused on the reasons for the magnitude of landing errors in floor exercise in men's artistic gymnastics. Our goal is to determine the parameters of the landing characteristics which have an influence on the magnitude of landing mistakes. We analyzed flips which were performed by all gymnasts (n = 97) competing in the qualification rounds of the European Championships in the year 2004 in Ljubljana. We defined the variables according to the theoretical model for the evaluation of flip landings in floor exercises. The results show that a soft landing is most effective, incomplete twists are the reason for large errors, landing after performing flips without twists is optimal with the feet together (unless the gymnast's abilities of his/her left and right leg are different) and the arms' positions at the time of the touch down should be upward.

Keywords: Gymnastics, floor exercise, landings, errors.

INTRODUCTION

Landing in modern gymnastics is one of the most important factors which determine the final rank of gymnasts at competitions. There are landings involved with every event using gymnastic apparatus. Most gymnasts perform in floor exercises where the competition routine performed is made up of several acrobatic elements. Each acrobatic jump element includes a take off phase, a flight phase and a landing.

The goal of the landing is to absorb the body's energy (kinetic energy being zero) produced at the take off phase. According to the conservation of mechanical energy, kinetic energy will be the same at take off and at landing if no external forces are applied to the body in the flight phase. This rule affects acrobatic elements, such as, for example, flips.

Each gymnast has to asses the amount and direction of energy in the flight phase and anticipate the amount and direction of energy at landing. The direction of kinetic energy at contact can be oriented towards or to the side of the energy from the flight phase. If the kinetic energy at landing is oriented towards the energy of the flight phase than the total sum of energies is equal to the difference between them and oriented in the direction of the greater one. If the direction of energies is the same than the total amount is equal to the sum of both energies. Therefore it is necessary for the stick landing to develop such initial conditions that the impulse of the ground reaction force would be oriented towards the energy of the flight phase and equal to its amount. These are characteristics of landings that occur after an independent acrobatic element or at the end of an acrobatic series. The ability of a gymnast to control a reaction force during the landing is limited by muscular coordination, the ability of an individual to predict the magnitude of loading, and the ability to overcome the load created at the time of contact with the surface (McNitt-Gray, Costa, Mathiyakom, & Requejo, 2001). If the body is not capable of efficiently controlling the loading at the time of landing, acute or overuse injuries can occur.

An additional problem is represented by the rule that feet should be together at landings (FIG, 2006). One of the most important factors affecting stability is the magnitude of the base support. The base of support is an area bounded by the outermost regions of the body in contact with the supporting surface. In the feet together stance, the base of support is small and this fact aggravates the gymnast's stability. Another factor that affects stability is the angle between the line of action of a body's weight and the boundaries of the base of support. When the line of action of a body's weight moves outside the base of support, stability is disrupted.

If the gymnast keeps his/her feet together at landing than he/she can increase his/her stability by horizontally positioning the center of gravity near the edge of the base of support of the oncoming external force and vertically positioning the center of gravity as low as possible.

Before the gymnast makes an (un)necessary step at landing he/she can perform modification movements. Research has shown that the distribution of momentum among segments at the flight phase and contact influences stability during interaction with the landing surface (McNitt-Gray, Hester, Mathiyakom, & Munkasy, 2001; Requejo, McNitt-Gray, & Flashner, 2002). Modifications in shoulder torque during the flight phase enables the gymnast to reach kinematic characteristics which are consistent with successful landings. After such a contact, the gymnast can circle the arms in the same or in the opposite direction to the direction of movement or lower his/her center of gravity. Modifications with hands help to preserve and transfer angular quantity (Prassas & Gianikellis, 2002). When the center of gravity is lowered, a time interval is enhanced, in which the interaction of the impulse of the ground reaction force with his/her muscles can be actively lowered.

Results from some research projects show a rather low success rate of landings at competitions (McNitt-Gray, Requejo, Costa, & Mathiyakom, 2001; Prassas & Gianikellis, 2002). At the Olympic games in 1996 in Atlanta McNitt-Gray et al. (1998) investigated landings from a high bar and from the parallel bars. Competitors performed twenty landings. Only one was performed without a mistake. Eight were over and eleven under rotated.

When performing acrobatic elements, mistakes can occur in every phase of the element. These phases are interdependent. Mistakes that occur in later phases can be in correlation with earlier phases. Therefore it is important to know types of landing mistakes in order to find the reasons for their occurrence.

In our research we will try to describe landing mistakes and find out what is the influence of the chosen variables on the magnitude of error. The subject of this research is: landings in floor exercise. The problem is to find out the reasons for the mistakes made.

MATERIAL AND METHODS

In our research we analyzed landings of flips performed after an independent flip or at the end of an acrobatic series of flips (n = 241). The analyzed flips were performed by all gymnasts (n = 97) who were competing in the qualification founds of the European Championships in 2004 in Ljubljana.

We defined variables according to a theoretical model for the evaluation of flip landings in floor exercise (Marinšek & Čuk, 2007). From the mentioned model we chose the following variables that describe landing:

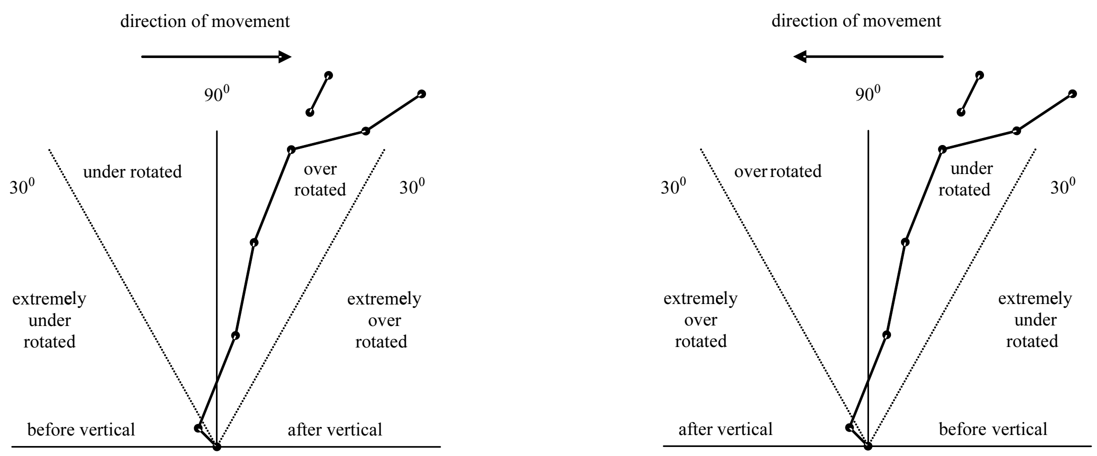
1. Style of landing:
   - on the feet,
   - in support*,
   - in a roll.

* We excluded from the research all somersaults performed with the support of both hands as our goal is to analyze the landings of flips that end up on the feet.

2. Angle of the body at contact (Fig. 1 and Fig. 2):
   - landings on feet (angle between the floor, heels and shoulders),
   - landings in a roll (angle between the floor, wrist and heels),
     - more than 31° after the vertical (very over rotated),
     - from the vertical to 30° (over rotated),
     - from 30° to the vertical (under rotated),
     - more than 31° before the vertical (very under rotated).

3. Base of support:
   - feet together,
   - ≤ shoulder width,

Fig. 1
Angles of the body at contact for landings on the feet



- > shoulder width,
- support with the hands.

4. Amortization:
   - stiff landing,
   - soft landing,
   - deep landing.

5. Inexactness of landing:
   - complete twists,
   - incomplete twists.

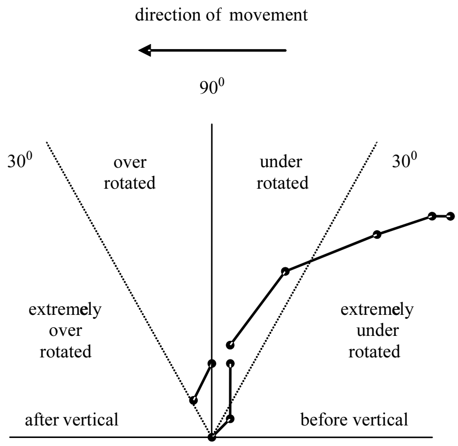
6. Hands position at contact:
   - forward,
   - outward,
   - upward,
   - downward,
   - backward.

7. Movement direction after landing:
   - no movement*,
   - forward,
   - backward,
   - to the side.

* We excluded from the research all flips performed which ended in a motionless landing as our goal is to analyze landings with mistakes.

For all variables we computed frequencies and their percentage in comparison to the magnitude of landing mistakes (crosstabs). With the Chi-square test, we determined differences between the chosen variables and flips with landing mistakes.

Fig. 2
Angles of the body at contact for the landings in a roll



RESULTS

Between the magnitude of error and the style of landing there are significant differences (TABLE 1). Landing in a roll has fewer errors from the code of points perspective. Flips landing on the feet have all errors related to a fall or a large error. The percentage of the occurrence of errors is relative to the same percentage as the number of landings on the feet (90.0%) and into a roll (10.0%).

TABLE 1
Distribution of the magnitude of error and the base of support

STYLE OF LANDING	Magnitude of error							Sum
	Small		Medium		Large		Fall	
	Step	Hop	Step	Hop	Touch	Support		
On feet	**48**	**83**	**54**	**20**		**4**	**8**	**217**
% within style of landing	22.1%	38.2%	24.9%	9.2%		1.8%	3.7%	100.00%
% within magnitude of error	78.7%	92.2%	96.4%	100.0%		100.0%	80.0%	90.00%
In roll	**13**	**7**	**2**				**2**	**24**
% within style of landing	54.2%	29.2%	8.3%				8.3%	100.00%
% within magnitude of error	21.3%	7.8%	3.6%				20.0%	10.00%
Sum	**61**	**90**	**56**	**20**		**4**	**10**	**241**
% within style of landing	25.3%	37.3%	23.2%	8.3%		1.7%	4.1%	100.00%

Chi-square test between magnitude of error and style of landing		
Value	**Degrees of freedom**	**Significance**
7.936	3	0.047

TABLE 2
Distribution of the magnitude of error and the base of support

	Magnitude of error							**Sum**
BASE OF SUPPORT	**Small**		**Medium**		**Large**		**Fall**	
	Step	**Hop**	**Step**	**Hop**	**Touch**	**Support**		
Feet together	**7**	**19**	**6**	**5**				**37**
% within base of support	18.9%	51.4%	16.2%	13.5%				100.00%
% within magnitude of error	11.5%	21.1%	10.7%	25.0%				17.10%
≤ shoulder width	**32**	**58**	**42**	**13**		**3**	**3**	**151**
% within base of support	21.2%	38.4%	27.8%	8.6%		2.0%	2.0%	100.00%
% within magnitude of error	52.5%	64.4%	75.0%	65.0%		75.0%	37.5%	69.60 %
> shoulder width	**9**	**6**	**6**	**2**		**1**	**1**	**25**
% within base of support	36.0%	24.0%	24.0%	8.0%		4.0%	4.0%	100.00%
% within magnitude of error	14.8%	6.7%	10.7%	10.0%		25.0%	12.5%	11.50%
support with hands							**4**	**4**
% within base of support							100.0%	100.00%
% within magnitude of error							50.0%	1.80 %
Sum	**61**	**90**	**56**	**20**		**4**	**8**	**217**
% within base of support	25.3%	37.3%	23.2%	8.3%		1.7%	3.7%	100.00%

Chi-square test between magnitude of error and base of support		
Value	**Degrees of freedom**	**Significance**
109.479	9	0.000

The base of support at landing and the magnitude of error show significant differences (TABLE 2). A bigger base of support means a larger margin of error (also according to the code of points). Most of the landings ended in a standing position with the legs apart up to the hip width (69.6%), much fewer ended in standing with the feet together (17.1%) and standing with the feet apart by more than the hips' width (11.5%) and the smallest number of landings ended using the support of the arms (1.8%).

Between the magnitude of error and the type of amortization there are significant differences (TABLE 3). The largest number of errors occurred during soft landings (58.9%), followed by stiff landings (37.3%) and deep landings (3.7%). Large errors and falls mostly occur in the case of deep landings (11.1% and 22.2%) and stiff landings (2.2% and 5.6%), and a lesser number in the case of a soft landing (0.7% and 2.1%).

TABLE 3
Distribution of the magnitude of error and amortization

	Magnitude of error							**Sum**
AMORTIZATION	**Small**		**Medium**		**Large**		**Fall**	
	Step	**Hop**	**Step**	**Hop**	**Touch**	**Support**		
Stiff landing	**16**	**31**	**22**	**14**		**2**	**5**	**90**
% within amortization	17.8%	34.4%	24.4%	15.6%		2.2%	5.6%	100.00%
% within magnitude of error	26.2%	34.4%	39.3%	70.0%		50.0%	50.0%	37.30%
Soft landing	**45**	**57**	**30**	**6**		**1**	**3**	**142**
% within amortization	31.7%	40.1%	21.1%	4.2%		0.7%	2.1%	100.00%
% within magnitude of error	73.8%	63.3%	53.6%	30.0%		25.0%	30.0%	58.90%
Deep landing		**2**	**4**			**1**	**2**	**9**
% within amortization		22.2%	44.4%			11.1%	22.2%	100.00%
% within magnitude of error		2.2%	7.1%			25.0%	20.0%	3.70%
Sum	**61**	**90**	**56**	**20**		**4**	**10**	**241**
% within amortization	25.3%	37.3%	23.2%	8.3%		1.7%	4.1%	100.00%

Chi-square test between magnitude of error and amortization		
Value	**Degrees of freedom**	**Significance**
24.792	6	0.000

TABLE 4
Distribution of the magnitude of error and the inexactness of landing

INEXACTNESS OF LANDING	Magnitude of error							Sum
	Small		Medium		Large		Fall	
	Step	Hop	Step	Hop	Touch	Support		
Without turn	**18**	**26**	**21**	**4**			**7**	**76**
% within inexactness of landing	23.7%	34.2%	27.6%	5.3%			9.2%	100.00%
% within magnitude of error	29.5%	28.9%	37.5%				70. %	31.10%
Complete twists	**39**	**52**	**25**	**15**		**3**	**1**	**135**
% within inexactness of landing	28.9%	38.5%	18.5%	11.1%		2.2%	0.7%	100.00%
% within magnitude of error	63.9%	57.8%	44.6%	75.0%		75.0%	10.0%	56.00%
Incomplete twists	**4**	**12**	**10**	**1**		**1**	**2**	**30**
% within inexactness of landing	13.3%	40.0%	33.3%	3.3%		3.3%	6.7%	100.00%
% within magnitude of error	6.6%	13.3%	17.9%	5.0%		25.0%	20.0%	12.30%
Sum	**61**	**90**	**56**	**20**		**4**	**10**	**241**
% within inexactness of landing	25.3%	37.3%	23.2%	8.3%		1.7%	4.1%	100.00%

Chi-square test between magnitude of error and inexactness of landing		
Value	**Degrees of freedom**	**Significance**
12.583	6	0.050

Between the magnitude of error and the inexactness of landing there are significant differences (TABLE 4). The highest frequency of errors is among flips with completed twists (56.0%), followed by flips without twists (31.1%) and flips with incomplete twists (12.3%), which have the highest number of medium errors (36.6%), large errors (3.3%) and falls (6.7%), while flips with completed twists have the largest number of small errors (67.4%).

TABLE 5
Distribution of the magnitude of error and the hands' position at contact

HANDS POSITION AT CONTACT	Magnitude of error							Sum
	Small		Medium		Large		Fall	
	Step	Hop	Step	Hop	Touch	Support		
Forward position	**6**	**23**	**10**	**1**		**2**	**3**	**45**
% within hands position	13.3%	51.1%	22.2%	2.2%		4.4%	6.7%	100.00%
% within magnitude of error	9.8%	25.6%	17.9%	5.0%		50.0%	30.0%	18.40%
Outward position	**37**	**47**	**29**	**14**			**1**	**128**
% within hands position	28.9%	36.7%	22.7%	10.9%			.8%	100.00%
% within magnitude of error	60.7%	52.2%	51.8%	70.0%			10.0%	53.10%
Upward position	**12**	**7**	**3**			**1**	**1**	**24**
% within hands position	50.0 %	29.2%	12.5%			4.2%	4.2%	100.00%
% within magnitude of error	19.7 %	7.8%	5.4%			25.0%	10.0%	9.80%
Downward position	**6**	**11**	**14**	**5**		**1**	**4**	**41**
% within hands position	14.6%	26.8%	34.1%	12.2%		2.4%	9.8%	100.00%
% within magnitude of error	9.8%	12.2%	25.0%	25.0%		25.0%	40.0%	17.00%
Backward position		**2**					**1**	**3**
% within hands position		66.7%					33.3%	100.00%
% within magnitude of error		2.2%					10.0%	1.20%
Sum	**61**	**90**	**56**	**20**		**4**	**10**	**241**
% within hands position	25.3%	37.3%	23.2%	8.3%		1.7%	4.1%	100.00%

Chi-square test between magnitude of error and hands position at contact		
Value	**Degrees of freedom**	**Significance**
30.423	12	0.002

TABLE 6
Distribution of the magnitude of error and the direction of movement after landing

DIRECTION OF MOVEMENT	Magnitude of error							Sum
	Small		Medium		Large		Fall	
	Step	Hop	Step	Hop	Touch	Support		
Forward	**36**	**61**	**30**	**16**		**3**	**1**	**147**
% within direction of movement	24.5%	41.5%	20.4%	10.9%		2.0%	0.7%	100.00%
% within magnitude of error	59.0%	67.8%	53.6%	80.0%		75.0%	10.0%	61.00%
Backward	**8**	**18**	**17**	**3**		**1**	**8**	**55**
% within direction of movement	14.5%	32.7%	30.9%	5.5%		1.8%	14.5%	100.00%
% within magnitude of error	13.1%	20.0%	30.4%	15.0%		25.0%	80.0%	22.50%
Aside	**17**	**11**	**9**	**1**			**1**	**39**
% within direction of movement	43.6%	28.2%	23.1%	2.6%			2.6%	100.00%
% within magnitude of error	27.9%	12.2%	16.1%	5.0%			10.0%	16.00%
Sum	**61**	**90**	**56**	**20**		**4**	**10**	**241**
% within direction of movement	25.3%	37.3%	23.2%	8.3%		1.7%	4.1%	100.00%

Chi-square test between magnitude of error and direction of movement		
Value	**Degrees of freedom**	**Significance**
23.306	6	0.001

Between the magnitude of error and the hands position at contact there are significant differences (TABLE 5). Gymnasts have mostly had their arms in an outward position (53.1%), ratherthan in a forward position (18.4%), a downward position (17.0%), an upward position (9.8%) or a backward position (1.2%). The highest number of small (55.6%) and medium range (56.6%) errors occurred with the "outward arms" position. The highest number of large errors (50.0%) occurred with the use of the forward arms position and the largest amount of falls occurred with arms in the downward position.

Between the magnitude of error and the direction of movement after landing, there are significant differences (TABLE 6). After landing, gymnasts mostly continued with their movement in the direction of the flip (61.0%), in much fewer cases in a direction counter to the flip (22.5%) and in a sideways direction (16.0%). The highest frequency of small (64.2%), middle range (60.5%) and large (75.0%) errors were performed in the case of movement in the same direction as the flip, the highest number of falls occurred in the case of movement in a direction counter to that of the flip (80.0%). Among small errors, the short hop (67.8%), and among medium errors, the overly large step (53.6%), prevailed.

TABLE 7
Chi-square test between the magnitude of error and other variables

Chi-square test between magnitude of error and other variables			
	Value	**Degrees of freedom**	**Significance**
Angle of the body at contact for landings on feet	20.826	15	0.142
Angle of the body at contact for landings in roll	1.346	3	0.718

Differences between the angle of the body at contact for landings on the feet and for landings in a roll were not significant (TABLE 7).

CONCLUSION

In men's artistic gymnastics, we differentiate three types of landing: in a standing position, into a roll out and into a front lying position. A perfect landing into a stand still position is the most difficult, while the other two types are easier.

To land in a stand still position, gymnasts use different positions of the feet. Mostly they perform standing with their legs apart up to hip width, but this type of landing was not very successful. A higher area of the base of support (standing with the legs apart, both left and right up to hip width) will be effective in the equilibrium sense only when some other factors (the biomechanical characteristics of the element and quality of motor control) will be fulfilled. Stability of body in both a forward and a backward direction (flips without twists) is not better if the feet are apart, as the stability angle does not rise as well, so to land with the legs apart has no biomechanical reason. Such landings with the feet apart (with a raised base of support) are successful in landing after a sideways flip and in flips with twists as the stability angle in a left/right direction is raised.

Results show that a soft landing is the most effective, while stiff landings and deep landings are reasons for more severe errors. Even when a gymnast performs a soft landing, he/she should be aware not to lower the knee angle so much as a moment of inertia in the direction of the flip can be too small and raises an angular velocity which causes an overly fast movement in the rotation direction.

Incomplete twists are reasons for large errors. Incomplete twists are technical errors which are directly related to airborne time and to the characteristics of take off. Landing with an incomplete twist is a very difficult task as the position of the gymnast is always different (the amount and sort of error is random). Only technically close to perfect elements should be included in the exercise.

Before gymnasts perform unnecessary hops or steps during the landing, they can also do some other correction movements – swinging their arms into the direction or into the opposite direction of the movement. The smallest number of errors was done while the gymnast had an upwards arms position at the moment of a touch down done with the feet. The highest number of errors were noticed when using the downward arms position. The upward arms position is the best (as an initial position) as the arms can swing forward, backward, or outward in accordance with the landing characteristics.

In conclusion we should emphasise again what is the opposite of the usual coaches' stereotypes:

- landing after flips without twists is optimal with the feet together (unless the gymnasts' abilities to use the left and right leg are different),
- the arms' position at touch down should be upward.

REFERENCES

Federation Internationale de Gymnastique. (2006). *Code of points*. Men's Technical Committee.

Marinšek, M., & Čuk, I. (2007). Theoretical model for the evaluation of salto landings in floor exercise. In N. Smajlovic (Ed.), *International Symposium New Technologies in Sport* (pp. 63–68). Sarajevo: Fakultet sporta i tjelesnog odgoja.

McClymont, D. (1999). *The bungy mechanics as an aid to trampoline coaching.* Retrieved 28. 6. 2006 from the World Wide Web: http://coachesinfo.com/category/gymnastics/71/

McNitt-Gray, J. L., Munkasy, B. A., Costa, K., Mathiyakom, D., Eagle, J., & Ryan, M. M. (1998). Invariant features of multijoint control strategies used by gymnasts during landings performed in Olympic competition. In *North American Congress of Biomechanics* (pp. 441–442). Canada, Ontario: University of Waterloo.

McNitt-Gray, J. L., Requejo, P., Costa, K., & Mathiyakom W. (2001). *Gender differences in vault landing location during the artistic gymnastics competition of the 2000 Olympic Games: Implications for improved gymnast/mat interaction*. Retrieved 28. 6. 2006 from the World Wide Web: http://coachesinfo.com/category/gymnastics/74/

McNitt-Gray, J. L., Hester, D. M., Mathiyakom, W., & Munkasy, B. A. (2001). Mechanical demand and multijoint control during landing depend on orientation of the body segments relative to the reaction force. *Journal of Biomechanics, 34(11),* 1471–1782.

McNitt-Gray, J. L., Requejo, P., Costa, K., & Mathiyakom, W. (2001). *Landing success rate during the artistic gymnastics competition of the 2000 Olympic Games: Implications for improved gymnast/mat interaction.* Retrieved 8. 6. 2006 from the World Wide Web: http://coachesinfo.com/category/gymnastics/75/

Prassas, S., & Gianikellis, K. (2002). Vaulting mechanics. In *Applied Proceedings of the XX International Symposium on Biomechanics in Sport – Gymnastics.* Caceres, Spain: University of Extremadura, Department of Sport Science.

Requejo, P. S., McNitt-Gray, J. L., & Flashner, H. (2002). Flight phase joint control required for successful gymnastics landings. *Medicine Science in Sports & Exercise*, *34(5),* 99.

CHYBY V DOSKOCÍCH V PROSTNÝCH MUŽŮ

(Souhrn anglického textu)

Ve výzkumu jsme se zaměřili na příčiny chyb v doskoku v prostných v mužské sportovní gymnastice. Naším cílem je stanovit parametry charakteristik doskoku, které ovlivňují závažnost chyby v dopadu. Analyzovali jsme přemety provedené všemi gymnasty (n = 97) soutěžícími na kvalifikační soutěži Mistrovství Evropy 2004 v Lublani. Podle teoretického modelu pro hodnocení doskoků při přemetech v prostných jsme stanovili proměnné. Výsledky ukazují, že nejúčinnější je měkký doskok, zatímco neúplné obraty způsobují závažné chyby. Doskok po přemetu bez obratu je optimální s nohama u sebe (pokud se gymnastovy schopnosti levé a pravé nohy neliší) a se vzpaženýma rukama.

Klíčová slova: gymnastika, prostná, doskok, chyby.

M.Sc. Miha Marinšek

University of Maribor
Faculty of Education
Koroska cesta 160
2000 Maribor
Slovenia

Education and previous work experience

University degree in Faculty of Sport at the Univerity of Ljubljana. Master of Science in Faculty of Sport at the Univerity of Ljubljana. Lecturer at the Faculty of Education. Head coach of Slovenian gymnastics team under 14 years.

First-line publications

Marinšek, M., & Kolar, E. (2007). A comparison of selected kinematical characteristics between successful attempts of elements Diamidov, Diamidov with 180° turn and Diamidov with 360° turn. *Kalokagathia, 47(3, 4),* 138–148.

Marinšek, M., Veličković, S., & Kolar, E. (2007). Differences in morphological characteristics and motor abilities between Slovenian and Serbian male gymnasts. *Stud. Kinantropol.*, *8(2),* 61–67.

Marinšek, M., & Čuk, I. (2007). Theoretical model for the evaluation of somersault landings in floor exercise. In N. Smaljović (Ed.), *Zbornik naučnih i stručnih radova* (pp. 63–68). Sarajevo: Fakultet sporta i tjelesnog odgoja.