A CASE STUDY ABOUT DIFFERENCES IN CHARACTERISTICS OF THE RUN-UP APPROACH ON THE VAULT BETWEEN TOP-CLASS AND MIDDLE-CLASS GYMNASTS

Saša Veličković, Dragoljub Petković, Emilija Petković

University of Niš, Faculty of Sport and Physical Education, Serbia

Original research article

Abstract

The aim of this research was to determine the differences in run-up velocity of the last ten steps between top class athletes and middle class athletes. The examined sample consisted of four athletes participating in the finals of the World Championship in December 2002, and two participants of the World Cup in Maribor 2006. Run-up velocity was registered by the kinematic analysis system APAS and the OPTO-TRACK-Microgate system. Statistical significance of the difference in arithmetic means of run-up parameters was determined by t-test and U-test. Results showed a progressive increase in velocity in both examined groups and the fact that all gymnasts reach higher velocity on their last step (Top – 9.95m/s; Middle – 8.57m/s). Top class gymnasts have a significantly lower level of velocity at the initial part of the analysed run-up (3.2m/s related to 5.4 m/s), while at the end of the run-up they reach higher velocity values and bigger progression from step to step in comparison with middle class gymnasts, which is also statistically significant. In the top class gymnast group a velocity peak was observed on the 6th step with a slight decrease in velocity on the 7th step and increasing again for the last three steps before the vault board. Unlike the middle class gymnast group where a constant increase in velocity from the beginning to the end of the analysed run-up was observed. These results suggest that middle class gymnasts should try to change their run-up approach to the vault in a manner that follow as closely as possible the run-up of top class gymnasts.

Keywords: *men artistic gymnastics, vault, run-up, velocity, steps.*

INTRODUCTION

The vault is a apparatus characterised by a complex and very short movement (no longer than 7 seconds on average) which can be divided into several very important phases: run-up, preparation for the take-off and contact with the vault board, take-off, the first flight phase, hand take-off, second flight phase and landing. The basic task of gymnast's vault is to facilitate as much time as possible in the second flight, and enable gymnast's body ballistic curve movement with maximum high peak (distance is of no significance) and angular momentum. For this purpose, the athlete uses kinetic energy, mostly generated during the run-up and the arms and legs take-off force.

The run-up is one of the basic preconditions for performance on the vault. The run-up enables the gymnast to achieve the necessary horizontal velocity, which is of outmost importance for proper development of the next phases. During the vault performance, the run-up is technically very similar to the run-up for long jump in athletics (Petrovic et al., 1995). The basic difference between the long jump run-up and the vault run-up is that in the long jump run-up the jumper aims to generate his or her maximum velocity, while during the vault run-up velocity is always slightly lower than the athlete's abilities. However, both the jumper and the gymnast have the same goal - to generate the highest possible velocity in the take-off moment. Successful jumping on the vault board can only be enabled by optimal run-up velocity (Cuk & Karacsony, 2004). In this sense, the research project revealed the importance of reaching the highest possible, but controlled, velocity for the gymnast (Sands, 1984, Meeuwsen & Magill, 1987; Krug et al., 1998). Krug and associates (1998) underlined the importance of run-up velocity and precision of the board take-off, and the latest research has emphasized the importance of optimal run-up velocity for the purpose of obtaining better visual perception of the vault board and vault during the I vault phase (Bradshaw 2004). The above mentioned authors insist upon additional trainings which should include improving the visual regulation of movement during the run-up. Krug and associates (1998) used a laser apparatus to determine he average run-up velocity for women gymnasts during the handspring type vault as 7.3 m/s, during the Yurchenko type vault as 6.98 m/s and during the Tsukahara vault as 7.28 m/s. The highest recorded velocity for a female gymnast was 7.9m/s. For men who perform medium vaults, the run-up velocity should be from 7.5 to 8.5 m/s, for heavy vaults from 8.5 to 9.5 m/s and for double salto vaults velocity should be over 10 m/s (Cuk and Karacsony, 2004). The maximum run-up velocity is not generated due to difficulties in the motor control of movements during the jump on the board (the location of the take-off is precisely defined as well as the location for the take-off during the preparation phase). A factor that prevents reaching the maximum velocity is a short run-up distance. In the 1950s Henry & Trafton (1951) proved that a sprinter reaches approximately 95% of maximum velocity over a 20m run.

A frequently researched problem is the connection between the run-up velocity and the final grade for a variety of vaults. Sands and Cheetham (1986) found there was a connection between the run-up velocity peak and the vault grade. On the other hand, Sands & McNeal (1995) measured the run-up velocity during gymnasts' vaults with a high precision apparatus (infrared interval timer) and recorded a weak connection between the maximum velocity and the vault grade. Additionally, when using the same parameters it turned out that on the female junior level, there was no statistically significant connection (Sands, 2000). Observations of vault mechanics showed that a higher run-up velocity is much more favourable for creating enough impulse to reach high and far in the second run-up phase. Takei thoroughly dealt with this problem and made a significant contribution in the analysis and modelling of the vault phases for both female and male gymnasts (Takei, 1988, 1989, 1990, 1991; Takei and Kim, 1990, Takei et al., 1990). One part of the research project focused on observations of the running technique which was found to be fairly bad. Thus, the conclusion of this part of the project was that gymnasts spend little time working on their running technique (Mann, 1985; Mero, Komi & Gregor, 1992; Sands & McNeal, 1999).

Two evolutionary changes in sports gymnastics have occurred in the last decade. One change refers to the change of rules and the grading system and the other one relates to the introduction of the new type of vault - the Pegaz (Knoll & Krug, 2002; Sands & McNeal, 2002). One of the basic reasons behind these changes is gymnast's safety. The latest research (Naundorf et al., 2008) analysing run-up velocity on vault (comparing two World Champions 1997 and 2007) points to the tendency to increase the analysed parameter for both women and men. The appearance of the new, much safer vault device largely contributes to this. Additionally, the same authors claim that there is no difference in running velocity between men and women as far as Yurchenko vault is concerned.

This research is dealing with the difference in the run-up velocity of top class gymnasts (TCG) and middle class gymnasts (MCG). The aim of the research is to determine the differences in velocity in the last ten steps between top vault gymnasts, finalists of the World Championship 2002 in Debrecen (Hungary), and middle class gymnasts from the Republic of Serbia, the finalists of the World Cup in Maribor (Slovenia).

METHODS

The sample of examinees consisted of four top vault gymnasts, participants in the World Championship finals in Debrecen (2002), and two middle class gymnasts of the Serbian team, finalists of the World Cup in Maribor (2006). All gymnasts jumped their most difficult jumps and were able to maximise their scores. Only the direct vaults were taken into consideration (all analysed jumps were performed successfully, without falls). Differentiation of first class gymnasts was performed based on the difficulty of the vaults which were performed at the above mentioned competitions:

Top class gymnasts:

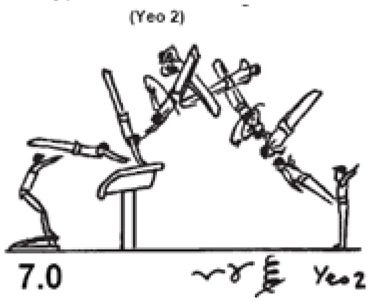

Figure 1. *Li Xiao Pen CHN – WS Debrecen 2002. - Handspring fwd. and salto fwd.str. w. 5/2t. (num. vault- 336)(FIG, 2009).*

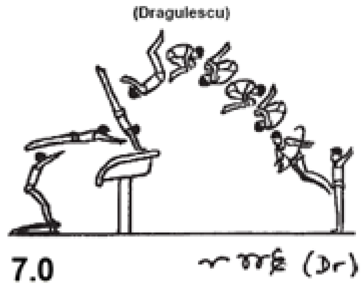

Figure 2. *Marijan Dragulesku ROM - WS Debrecen 2002. - Roche with ½ turn (num. vault- 338) (FIG, 2009).*

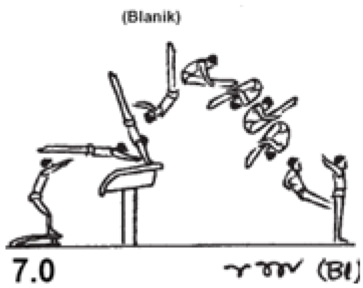

Figure 3. *Blanik POL - WS Debrecen 2002. - Handspring fwd. and dbl. salto fwd. Piked (num. vault- 340) (FIG, 2009).*

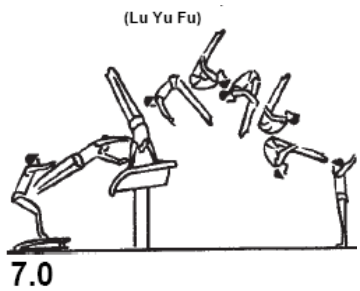

Figure 4. *Evgenij Kryukov RUS - WS Debrecen 2002. - Tsukahara with salto bwd. piked (num. vault- 443) (FIG, 2009).*

Middle class gymnasts:

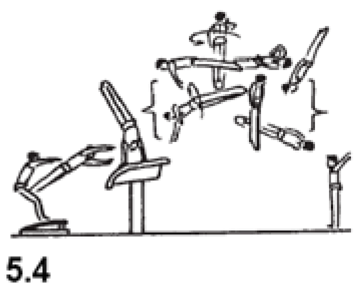

Figure 5. *Miloš Paunović SRB - WC Maribor 2006. - Tsukahara str. w. 1/1 t. (num. vault- 427) (FIG, 2009).*

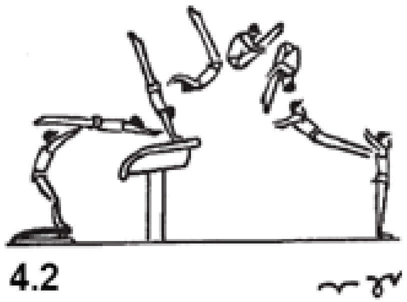

Figure 6. *Miloš Paunović SRB - WC Maribor 2006. - Handspring fwd. and salto fwd. p.(num. vault – 319) (FIG, 2009).*

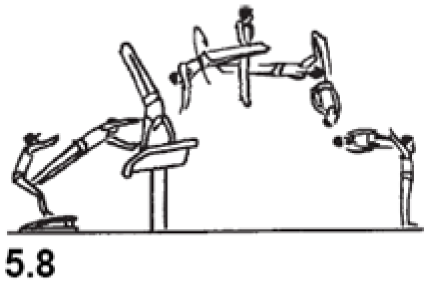

Figure 7. *Aca Antić SRB - WC Maribor 2006. - Kasamatsu str. with ½ t. (num. vault- 428) (FIG, 2009).*

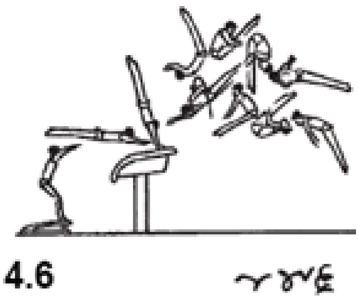

Figure 8. *Aca Antić SRB - WC Maribor 2006. - Handspring fwd. and salto fwd. p.w.1/2 t. (num. vault – 320) (FIG, 2009).*

The variable sample consisted of run-up velocity parameters (of each individual step) during the vault. Considering that the vault length varied for different gymnasts, the last 10 steps were chosen in order to obtain equal form for further analysis. Velocity parameters were measured by Laboratory for Biomechanics Analysis of the Faculty of Physical Education in Ljubljana (Slovenia) by applying well tested system and software for kinematic analysis (APAS - Ariel Performance Analysis System 1995) and the OPTO-TRACK-Microgate system. By using the first system (APAS, two video cameras 50Hz) the standard procedure calculated velocity of each individual step at the World Championship 2002 in Debrecen: (a) data acquisition; b) data processing in six sub phases: 1) digitalization of video recording; 2) digitalization of comparative body parts; 3) transformation in three dimensional space; 4) filtering data; 5) calculating kinematic parameters; 6) data presentation). The other system detected velocity in each step at a World Cup Meeting in Maribor. The OPTO-TRACK-Microgate system is comprises optical sensors placed along the whole track (three centimetres apart, frequency 1000 Hz) and a computer for data storing and processing. The system enabled the measuring of: period of contact with the surface, period of flight, step length, step frequency, velocity in each step and acceleration. Only the velocity parameters in each step were used for this research (the last ten steps before jumping on the vault board).

Student t- test for determining statistical significance of difference between the top gymnasts group and the middle class gymnasts group was used for small independent samples. Having in mind that small number of samples is included; a non parameter procedure Man- Whitney U test was used for the purpose of examining the achieved results. SPSS 16 for Windows was used for statistical data processing.

RESULTS

Table 1 shows mean values and standard deviations of velocity indicators in each step for both groups.

Table 1. *Means and Standard Deviation of velocity indicators in each individual step.*

	TOP			MIDDLE		
	N	Mean	SD	N	Mean	SD
STEP 1	4	3.223	2.044	4	5.434	0.167
STEP 2	4	4.495	1.675	4	5.806	0.271
STEP 3	4	5.243	0.784	4	6.150	0.527
STEP 4	4	6.215	0.862	4	6.797	0.223
STEP 5	4	7.043	1.024	4	7.104	0.227
STEP 6	4	7.665	1.220	4	7.384	0.228
STEP 7	4	7.223	0.392	4	7.564	0.347
STEP 8	4	7.713	0.607	4	7.901	0.259
STEP 9	4	8.578	0.178	4	7.996	0.430
STEP 10	4	9.950	0.743	4	8.573	0.234

Insight into numerical values of arithmetic means (Table 1) as well as the graphic review (Figure 9), indicate the following:

1) There is a progressive increase of velocity in both groups and all gymnasts achieve the highest velocity values in the last step (Top – 9.95m/s; Middle – 8.57m/s);
2) Top class gymnasts have significantly lower velocity level at the beginning of the analysed part of the run-up (3.2m/s as opposed to 5.4 m/s), while at the end of the run-up they reach higher values in comparison with middle class gymnasts;
3) Top class gymnasts show velocity peak in the sixth step, velocity is then reduced in the seventh step and again rapidly increased in the last three steps in front of the board. Middle class gymnasts, however, show a constant velocity increase from the beginning to the end of the analysed run-up (Figure 9).

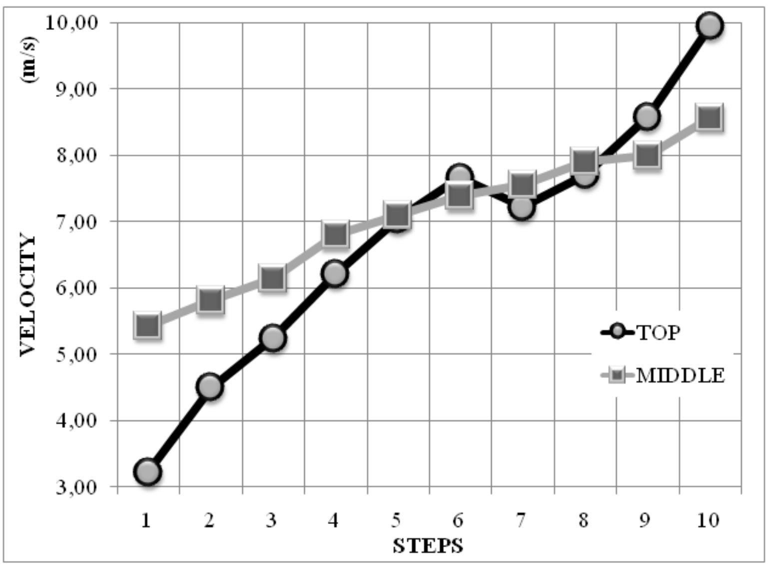

Figure 9. *Mean values of individual step velocity for top class and middle class gymnasts.*

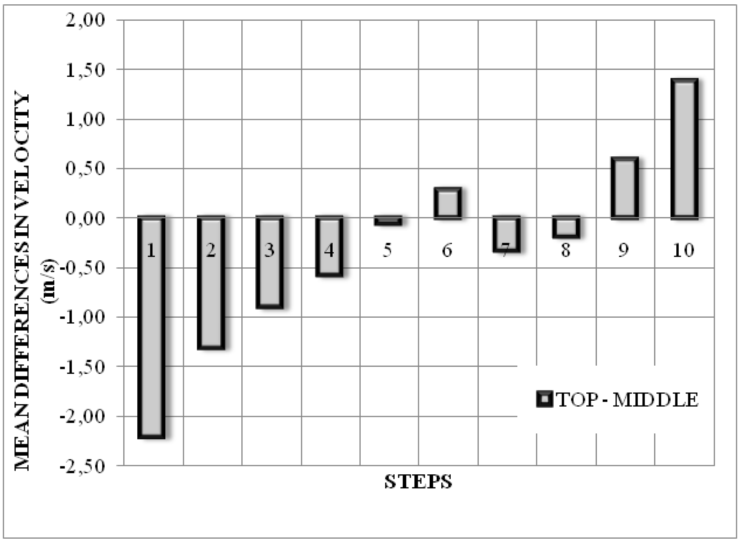

Figure 10. *Absolute differences in each step velocity between TCG and MCG.*

The following has been noted:

1) The differences in run-up velocity show for the initial part of the analysed run-up a significantly high level (above 2m/s) and are in favour of higher step for MCG;

2) As the gymnast approaches the vault board, the numeric differences of arithmetic means gradually decrease up to the fifth step, at which point the differences are minimal.

3) In the sixth step (take-off leg step) a difference was observed in favour of a higher average velocity level for TCG.

4) The run-up velocities in the seventh and the eights step are again higher for MCG;

5) In last two steps velocities significantly increase and are in favour of TCG.

Results of T-test and U-test which help to determine statistic significance of differences in arithmetic means (Figure 10) are presented in Table 2.

Table 2. *Results of testing statistic significance of differences in arithmetic means (Student T-test and Mann-Whitney test).*

TOP – MIDDLE

	Independent Samples Test		Mann-Whitney U (U-test)		
	t	p	U	Z	p
STEP 1	-2.16	0.11	11	-1.44	0.18
STEP 2	-1.56	0.26	12	-1.31	0.23
STEP 3	-2.61	**0.02**	5	-2.22	**0.03**
STEP 4	-1.34	0.27	11	-1.44	0.18
STEP 5	-0.12	0.91	20.5	-0.20	0.85
STEP 6	0.46	0.68	18	-0.52	0.66
STEP 7	-1.63	0.13	10	-1.57	0.14
STEP 8	-0.60	0.59	19	-0.39	0.75
STEP 9	2.58	**0.02**	5	-2.22	**0.03**
STEP 10	5.73	**0.00**	0	-2.89	**0.01**

A statistically relevant difference between arithmetic means was noted in the third step in favour of higher velocity for MCG (Table 2 and Figure 10). A statistically relevant difference was also noted between the penultimate and the last step; it goes in favour of higher velocity for TCG.

Using the available values, it was also possible to calculate differences in velocity of two adjacent steps (Figure 11) and to determine the progression of the run-up velocity which provided more essential information for this research.

In TCG the run-up velocity progression of two adjacent steps increases, and has tendency to gradually reduce the velocity differences up to the seventh step when a decrease occurs. The velocity is reduced by 0.44 m/s in the seventh step compared to the sixth step (Figure 11). Immediately after the seventh step, the velocity level increases progressively and this trend is maintained to the last step (step prior to jumping on the vault board).

In MCG, the velocity increment is significantly different from the velocity increment for TCG. Velocity in adjacent steps increases constantly (by around 0.30 m/s) and there is no decrease (constantly accelerating). Major differences have been identified between the third and the forth step (0.65 m/s), and the ninth and the tenth step (0.58 m/s) – (Figure 11). The increase and decrease of velocity curve (triangles) is similar to the TCG performance curve, but with smaller fluctuations. The key difference is the difference in velocity between the eighth and the ninth step which significantly increases (large positive rate) for TCG and decreases (negative rate) for MCG.

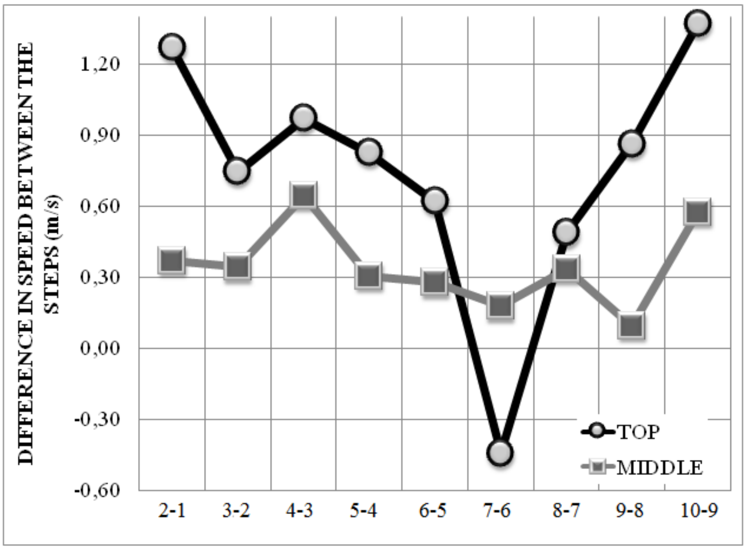

Figure 11. *Average values of differences in velocity of adjacent steps for TCG and MCG.*

More specifically, TCG significantly increases velocity in the transition from the eighth to the ninth step, while MCG increases velocity (positive rate) but the increase tendency reduces with the following steps. These differences are statistically relevant at levels 0.01 and 0.02 (Table 3). Statistically relevant is also the velocity increment in the transition from the ninth to the tenth step, i.e. greater acceleration for TCG.

Table 3. *Results of testing the statistical significance of differences in arithmetic means of velocity increments in adjacent steps (Student T-test and Mann-Whitney test).*

TOP – MIDDLE A

	Independent Samples Test		Mann-Whitney U		
	t	p	U	Z	p
STEPS 2-1	1.93	.140	7.5	-1.90	.056
STEPS 3-2	1.11	.285	18.0	-.52	.661
STEPS 4-3	.96	.354	14.0	-1.04	.343
STEPS 5-4	.87	.447	20.0	-.26	.851
STEPS 6-5	1.42	.181	15.0	-.91	.412
STEPS 7-6	-1.12	.341	15.5	-.85	.412
STEPS 8-7	.41	.702	18.0	-.52	.661
STEPS 9-8	2.98	**.011**	4.0	-2.35	**.018**
STEPS 10-9	3.06	**.009**	5.5	-2.16	**.026**

DISCUSSION

Our results show a clear difference in the run-up tactics the two groups. TCG has a significantly lower level of velocity in the initial part of the analysed run-up and a significant increase in velocity at the end of the run-up, i.e. in the moment when it is essential to reach the highest velocity which is immediately prior to jumping on the vault board (Cuk & Karacsony, 2004). The differences in this part of the run-up are especially statistically relevant (Table 2). Apart from the statistically relevant high level of velocity at the end of the run-up, a significant increase of velocity at the end of the run-up for TCG was also found. Why is this relevant when it comes to vaults of various coordination complexity (Sands & Cheetham, 1986)? A higher level in the run-up velocity, immediately prior to jumping onto the board, provides a greater potential for a strong jump onto the board and the vault. And when a strong jump and a strong hand take-off are performed after the first flight phase, a greater potential, i.e., greater kinetic energy, is generated which facilitates a higher second flight phase (Krug et al., 1998). A high second flight phase provides more time and a greater potential for a more complex rotation around the vertical and transversal axis. MCGs have lower run-up velocity prior to jumping on the vault board and therefore a lesser potential for more complex vaults. Nevertheless, the level of velocity in MCG was sufficient for a successful performance of simple vaults (difficulty range from 4.2 to 5.6). But the question is whether such momentum could generate a sufficient amount of kinetic energy for mastering more complex vaults. It appears that this specific run-up mode is one of the essential arguments that differentiates top class gymnasts from middle class gymnasts.

Furthermore, TCGs better prepare for a good - that is, rapid, strong and precise - jump. They start the initial part of the analysed run-up with a lower level of velocity than MCGs and rapidly increase and then gradually decrease it up to the fifth step; after that a steady decrement of velocity is noted (compared to MCGs who increase the velocity level gradually throughout the analysed run-up – Figure 11). In this part of the run-up a statistically relevant difference is noted in the third step (Table 2). This again raises the question of the run-up strategy for TCG. The answer is presumably in the complexity of the vault they perform. Namely, complex vaults (vaults of the highest difficulty – 7.0) require not only a strong hand and leg take-off, but also a precise take-off. Precision requires a specific invasion angle for legs on the vault board and for hands on the vault, as well as a precisely found contact point on the vault board and on the vault. This is only possible by performing an optimal, controlled and carefully planned run-up. It can be concluded that TCGs assess the distance from the vault board and the vault in the initial part of the analysed run-up, that is, in the transition from the sixth to the seventh step, since velocity in this part of the run-up slightly decreases (the first velocity peak). It can be assumed that gymnasts slightly decrease velocity in order to asses the vault, aiming to jump onto the board as precisely as possible and to successfully perform further phases of the vault (Krug et al. 1998; Bradshaw, 2004). After the evaluation of the distance from the vault board and the vault, TCGs can direct all their energy in the last three steps into creating the maximum hand and leg take-off as a vital part of vault performance with movements of very high coordination complexity.

MCGs have nearly constant progression and increment of velocity for the better part of the analysed run-up and this seems to be a disadvantage for a successful preparation to the jumping onto the board. A careful analysis of Figure 11 shows a bigger decrement in velocity between the eights and the ninth step (two steps prior to jumping onto the bard). This can indicate that MCGs acquire the information about the distance from the board and the vault in eighth and the ninth step, which is significantly later than TCGs. This could therefore be one of the arguments why they can perform only vaults of lower complexity.

An anomaly is noted in the last ten steps of the run-up. The leg which performs the take-off dominates velocity increments. A broken curve in Figure 11 shows in the first, third, fifth, seventh, and ninth boxes (progression of the leg which performs the take-off) mostly higher values than in adjacent boxes (Figure 11). This can indicate an opposite leg injury for MCGs (causing a slower increment) or a poor running technique.

CONCLUSION

These results suggest that MCGs should try to change their run-up to the vault follow as much as possible the pattern set by TCGs. During the training process, it is necessary to focus not only on maximum velocity but also on the proper progression to the vault, as there is a high correlation with the vault progression for TCGs. If this does not result in a higher second flight phase, the error is in other vault phases, more specifically, in the jumping onto the board and a hand take-off which beside the run-up contribute to increases in the amount of kinetic energy.

REFERENCES

Bradshaw, E. (2004). Target-directed running in gymnastics: a preliminary exploration of vaulting. Sports Biomechanics, 3 (1):125-144.

Čuk, I. & Karacsony, I. (2004). Vault, Methods, Ideas, Curiosities, History. Ljubljana: ŠTD Sangvinčki.

FIG (2009). Code of Points Men Artistic Gymnastics. Loussane: FIG

Henry, F. M. & I. R. Trafton. (1951). The velocity curve of sprint running. Res. Quar, 22(4): 409-422.

Knoll, K. & Krug, J. (2002). The vaulting table - a new vaulting apparatus in artistic gymnastics. Retrieved 11.06.2003, fr. http://www.coachesinfo.com/category/gymnastics/61/

Krug, J., K. Knoll, Kothe, T. & Zocher, H.D. (1998). Running approach velocity and energy transformation in difficult vaults in gymnastics. In: ISBS '98 XVI International symposium on biomechanics in sports, edited by H. J. Riehle, and Vieten, M. M. Konstanz, Germany: UVK – Universitatsverlag, Vol. 1: 160-163.

Mann, R. (1985). Biomechanical analysis of the elite sprinter and hurdler. In:

The elite athlete, edited by N. K. Butts, Gushiken, T. T., and Zarins, B. Jamaica, NY: Spectrum, p. 43-80.

Meeuwsen, H. & Magill, R.A. (1987). The role of vision in gait control during gymnastics vaulting. In: Diagnostics, treatment and analysis of gymnastic talent, edited by T. B. Hoshizaki, Salmela, J. H., and Petiot, B. Sport Psyche Editions, p. 137-155. Montreal, Canada

Mero, A., Komi, P.V. & Gregor, R.J. (1992). Biomechanics of sprint running. Sports Med., 13(6): 376-392.

Naundorf, F., Brehmer, S., Knoll, K., Bronst, A. & Wagner, R. (2008). Development of the velocity for vault runs in artistic gymnastics for the last decade. In: Kwon,Y., Shim,J., Shim, J.K., Shin, I. ISBS XXVI Conference, p. 481-484. Seoul, Korea.

Petrović, J., Buđa, P., Radosavljević, J., Sedić, P., Petković, D. & Grbović, M. (1995). Sportska gimnastika II deo. Beograd: Fakultet fizičke kulture Univerziteta u Beogradu.

Sands, W. A. (1984). Coaching women's gymnastics. Champaign, IL: Human Kinetics.

Sands W. A. (2000). Vault Run Speeds. Technique, 20 (4): 1-5.

Sands, W. A., & Cheetham, P. J. (1986). Velocity of the vault run: Junior elite female gymnasts. Technique, 6: 10-14.

Sands, W. A., & Mcneal, J. R. (1995). The relationship of vault run speeds and flight duration to score. Technique, 15(5): 8-10.

Sands, B., & Mcneal, J. R. (1999). Body size and sprinting characteristics of 1998 National TOP's athletes. Technique, 19(5): 34-35.

Sands, W. A., & Mcneal, J. R. (2002). Some Guidelines on the Transition from the Old Horse to the New Table. Technique, 22: 22-25.

Takei, Y. (1988). Techniques used in performing the handspring and salto forward tucked in gymnastic vaulting. I.J.S.B., 4(3): 260-281.

Takei, Y. (1989). Techniques used by elite male gymnasts performing a handspring vault at the 1987 Pan American Games. I.J.S.B., 5(1): 1-25.

Takei, Y. (1990). Techniques used by elite women gymnasts performing the handspring vault at the 1987 Pan American Games. I.J.S.B., 6(1): 29-55.

Takei, Y. (1991). A comparison of techniques used in performing the men's compulsory gymnastic vault at 1988 Olympics. I.J.S.B., 7(1): 54-75.

Takei, Y., Blucker, E. P., Dunn, J. H., Myers, S. A. & Fortney, V. L. (1996). A three-dimensional analysis of the men's compulsory vault performed at the 1992 Olympic Games. J. Appl. Biom, 12(2): 237-257.

Takei, Y., & Kim, E. J. (1990). Techniques used in performing the handspring and salto forward tucked vault at the 1988 Olympic games. I.J.S.B., 6(2): 111-138.

Coresponding author:
Saša Veličković,
University of Niš,
Faculty of Sport and Physical Education,
Čarnojevića 10a,
18000 Niš,
E-mail: v.sale70@yahoo.com