Ivan Čuk[1]*
Stane Držaj[2]
Istvan Karacsony[3]

TRIPLE SALTO BACKWARD TUCKED FROM RINGS (A CASE STUDY)

TROJNI SKRČENI SALTO NAZAJ S KROGOV (ŠTUDIJ PRIMERA)

ABSTRACT

Since Jury Koroljev (Soviet Union) performed a triple salto backward tucked on rings for the first time at the European Championship in 1981, not many gymnasts have performed this extraordinary element. Before the Olympic Games in Sydney 2000 we made recording of the successful attempt of Zoltan Supola (height 1.69 m, weight 62.1 kg), a member of the Hungarian national team during preparations in Tata (Hungary). For kinematic analyses we used Sušanka's body model. Data were analysed with a 3D CMAS kinematical system. Forces on the rings were calculated with specially designed software for 2D inverse dynamics by Colja (1995). The triple salto backward is characterised by very high force (11.70 G) and momentum (4617 Nm) on the rings in the preparation phase, a very fast rotation around the x axis during the flight (860 °/s), a very small moment of inertia during the flight and it requires extreme grip strength in the preparation phase and during the flight (pulling knees as close as possible to the trunk), extreme strength and fast work of the trunk and leg flexors (receiving into and maintaining a tucked position), as well as extreme strength of the leg extensors (landing from 3.18m).

Keywords: biomechanics, kinematics, rings, triple salto backward tucked

[1] University of Ljubljana, Faculty of Sport, Slovenia
[2] Elderly home, Horjul, Slovenia
[3] Semmelweis University, Faculty of Physical Education Budapest, Hungary

****Corresponding author:***
University of Ljubljana, Faculty of Sport
Gortanova 22,
SI-1000 Ljubljana, Slovenia
Tel.: +386 1 5207700, fax: +386 1 5207750
E-mail: ivan.cuk@fsp.uni-lj.si

IZVLEČEK

Jurij Koroljev je leta 1981 na Evropskem prvenstvu kot prvi na svetu izvedel trojni skrčeni salto nazaj s krogov. Od takrat dalje ni imel veliko posnemovalcev, saj je prvina izjemno zahtevna. Pred olimpijskimi igrami leta 2000 v Sydneju smo posneli uspešno izvedbo trojnega skrčenega salta nazaj s krogov vrhunskega madžarskega telovadca Zoltana Supolo (telesna višina 1,69 m in telesna teža 62,1 kg) na pripravah v Tati (Madžarska) Kinematične analize smo izvedli s 3D CMAS sistemom, kjer smo uporabili Sušankim model človeka. Za izračun sil na kroge smo uporabili poseben računalniški program, ki ga je razvil Colja (1995). Za trojni skrčeni salto so značilne zelo velike sile na kroge (11,7G) in navor (4617Nm) v pripravljalnem delu prvine, zelo visoka kotna hitrost vrtenja v letu (860°/s), zelo majhen vzrtajnostni moment med letom. Prvina zahteva izjemno močan prijem v pripravljalnem delu in letu (močno vlečenje goleni k trupu), zahteva izjemno moč upogibalk trupa in nog (za izvedbo skrčenega položaja) in izjemno močne iztegovalke nog (doskok z višine 3,18 m).

Ključne besede: biomehanika, kinematika, krogi, trojni skrčeni salto nazaj

INTRODUCTION

The rings are today much more an apparatus of strength than an apparatus where swings are performed. It is believed that rings are of Italian origin, although Frenchman Amoros built a "swinging bar" in 1806 in his gym and this equipment is still used by acrobats in the circus and is called the "trapeze bar". The swinging bar has since then changed many shapes from triangular, a ladder etc. (Goehler, 1989). The ring structure introduced to gymnastics competitions at the turn of the 20th century has not changed to this day, although the material from which the frame and apparatus are made has. It became necessary to determine the compulsory parameters and quality of the apparatus used in Olympic competitions as the dimensions and materials used differed too much. This was determined by the International Gymnastics Federation in 1956 with the first FIG norms (Gregorka & Vazzas, 1983).

Code of Points for Men (FIG, 2009) describes exercise on the rings in Article 34: An exercise on rings is composed of swing, strength and hold parts in approximately equal portions. These parts and combinations are executed in a hang position, to or through a support position or to or through the handstand position and execution with straight arms should be predominant. For dismount gymnasts must perform at least a D-difficulty (difficulties are ranged from the easiest A to the most difficult G) dismount not to be penalised.

Since Jury Koroljev (Soviet Union) performed a triple salto backward tucked on rings for the first time at the European Championship in 1981 (Goetze & Uhr, 1994), not many gymnasts have achieved this extraordinary element. There are many reasons why this dismount has so rarely been seen. The first reason is found within the element itself – a very difficult dismount to show a perfect body form during the flight phase and a very difficult landing without small errors – and the second one is found within the FIG Code of Points – a very small reward for a gymnast if he performs it. In the Olympic cycle 1996 – 2000 only two gymnasts performed this dismount at big competitions like the Olympic Games, World and European Championships, namely Zoltan Supola (Hungary) and Dimitri Karbonenko (France). In the Olympic cycle 2000 – 2004 the Code of Points gave a reward of 0.3 bonus points for gymnasts who performed a triple salto backward tucked. Since 2006 the Code of Points (FIG 2006, 2009) has changed in philosophy so much that we cannot compare the Codes anymore. Since 2006 the final score is divided into exercise presentation score (from 10 points down) and difficulty score (from 0 points upward). The difficulty score consists of special requirements and the difficulty of elements. The difficulty of elements ranges from A (0.1 point) to G (0.7 points). In the latest Code of Points (2009) the triple salto backward tucked is defined as an F element (0.6 point). As another special requirement on the rings is a dismount of at least the D difficulty level, most gymnasts are performing a D difficulty dismount from the rings and very rarely do gymnasts show an E difficulty dismount and even more seldom an F dismount. The technique of the triple salto backward tucked is described as follows: from back swing to front swing: after the vertical position – where the head is very extended – the gymnast extremely pulls his arms down strongly and pushes sideways while strongly pushing his bent knees up and very quickly flexing his shoulders, hips, knees and head. Just after the inverted vertical hang, the gymnast releases the rings and grips his calf below the knees and tries to minimise the angle between his trunk and thigh as well as the angle between his thigh and calf and remains in this extremely tucked position for up to an approximately 11/4 salto backward. Then he starts to stretch and prepares for the landing. In the international literature there is no information about the triple salto backward from the rings (Prassas, 2008).

The aim of this research was to determine the basic biomechanical characteristics of the element in order to help coaches ascertain what they should focus on.

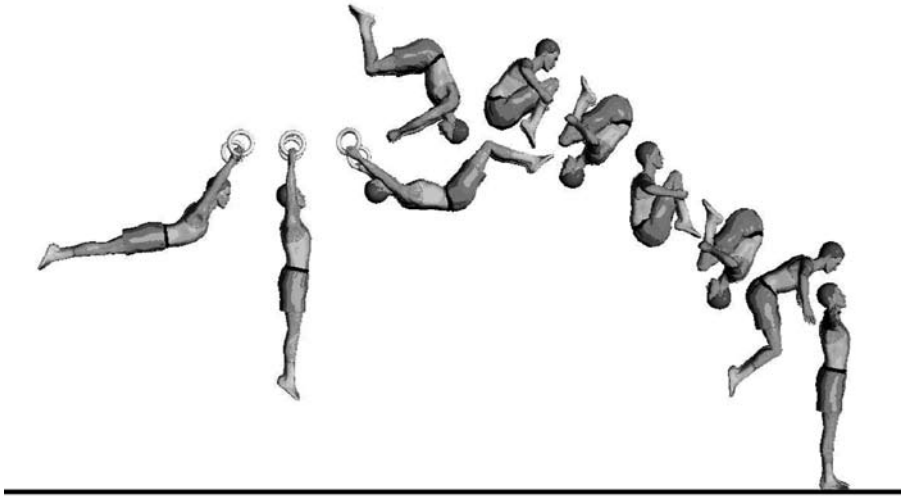


Figure 1. Triple salto backward tucked (Čuk & Karacsony, 2002)

METHODS

Before the Olympic Games in Sydney 2000 we made recordings of a successful attempt by Zoltan Supola (height 1.69 m, weight 62.1 kg), a member of the Hungarian national team during preparations in Tata (Hungary). The triple salto backward tucked was performed as one element only (not part of the whole exercise) and was perfectly landed. We recorded the movement with

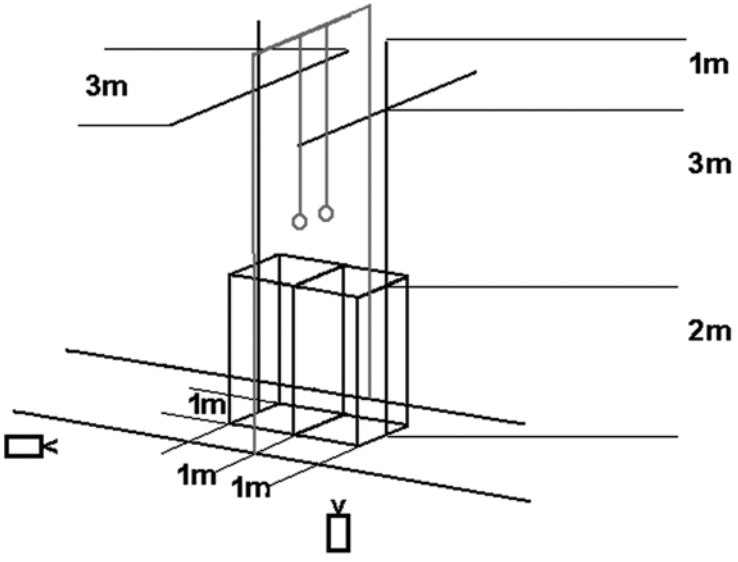
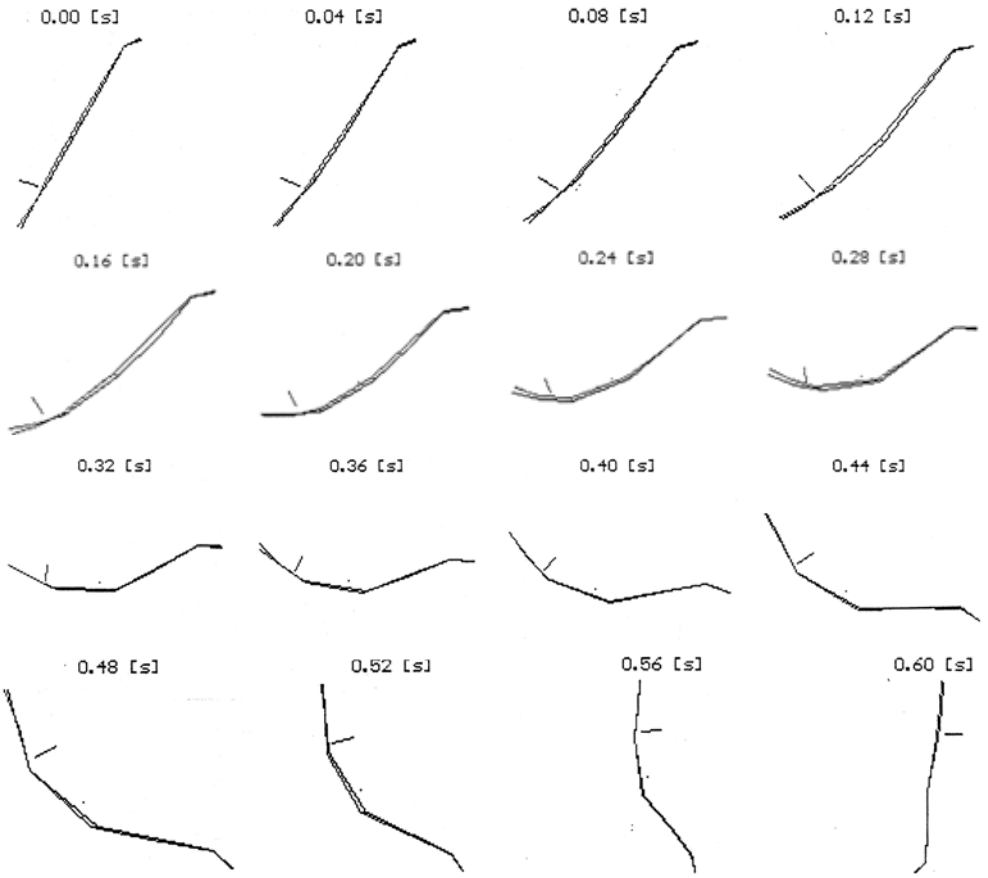


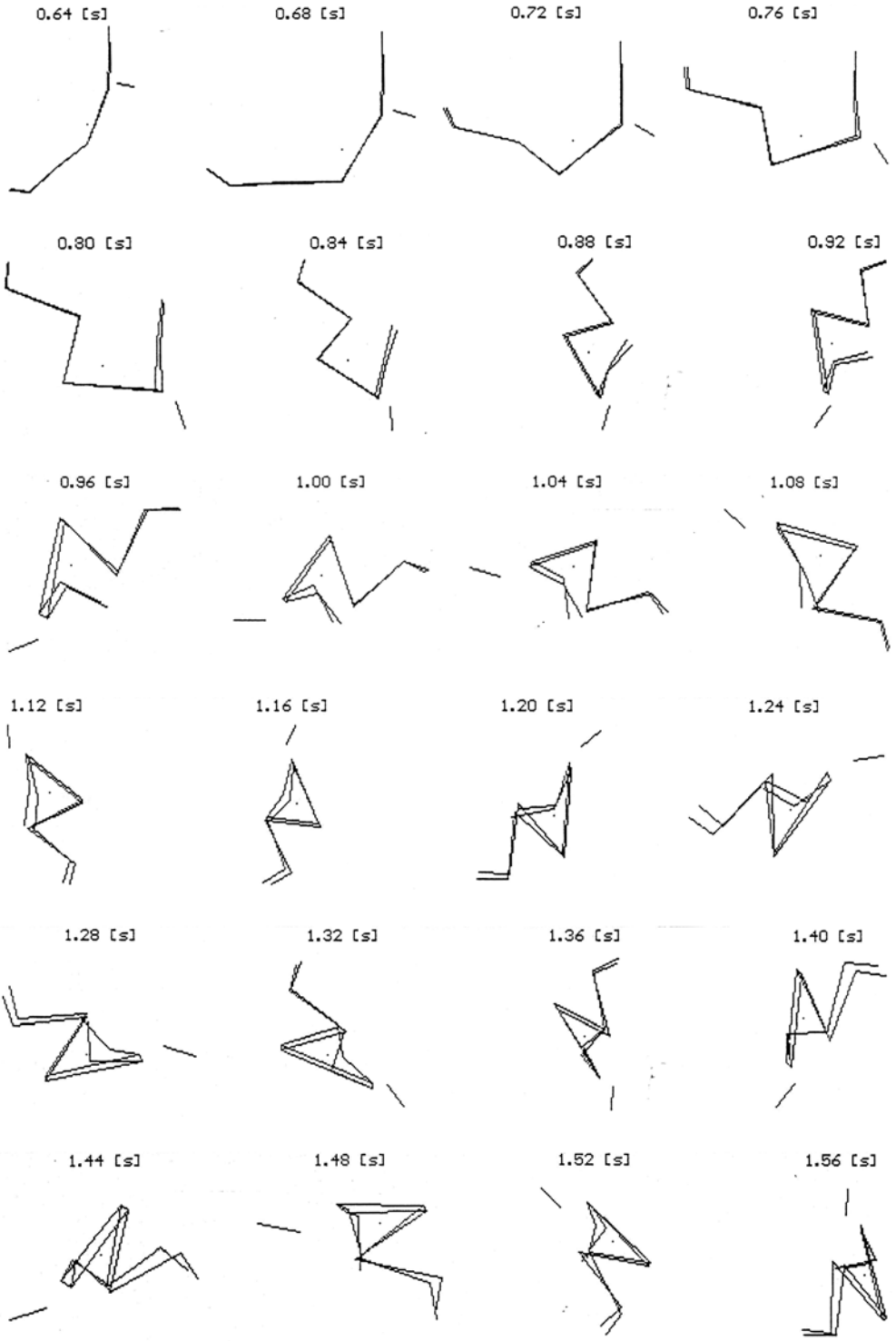
Figure 2. Definition of the space and position of the cameras

two video SONY DVCAM digital cameras with a frequency of 50 frames per second. For the definition of space we used two cubes 1x1x1 metre (placed one on other) and a special cross of 3 x 6m as shown in Figure 2 (with the cubes and cross we wanted to cover most of the positions of the gymnast within a defined space to avoid extrapolation of the input data). For the kinematic analyses we used Sušanka's (1987) 15 segment body model. Data were transformed into 3D with a direct linear transformation and smoothed with a digital filter 7 and analysed with a CMAS kinematic system. Forces on the rings were calculated with specially designed software for 2D inverse dynamics by Colja (1995); calculations used a simplified 7 segment (forearm, upper arm, head, trunk, thigh, calf, foot) model by Dempster (in Winter, 1979).

RESULTS AND DISCUSSION

We can divide the whole element into the following phases: preparation phase (time 0.00 to 0.88s; the preparation phase divided into three subphases: body within horizontal position (0.28s), body in vertical position (0.60s), phase of emphasised leg bending (0.72s)), moment of release (0.92s), flight (from 0.96 up to 1.88s; flight phase divided into three subphases: end of the first salto (1.20s), moment of maximum height (1.32s), end of the second salto (1.56s)) and the landing (1.92 up to 2.22s).




0.64 [s]
0.68 [s]
0.72 [s]
0.76 [s]
0.80 [s]
0.84 [s]
0.88 [s]
0.92 [s]
0.96 [s]
1.00 [s]
1.04 [s]
1.08 [s]
1.12 [s]
1.16 [s]
1.20 [s]
1.24 [s]
1.28 [s]
1.32 [s]
1.36 [s]
1.40 [s]
1.44 [s]
1.48 [s]
1.52 [s]
1.56 [s]

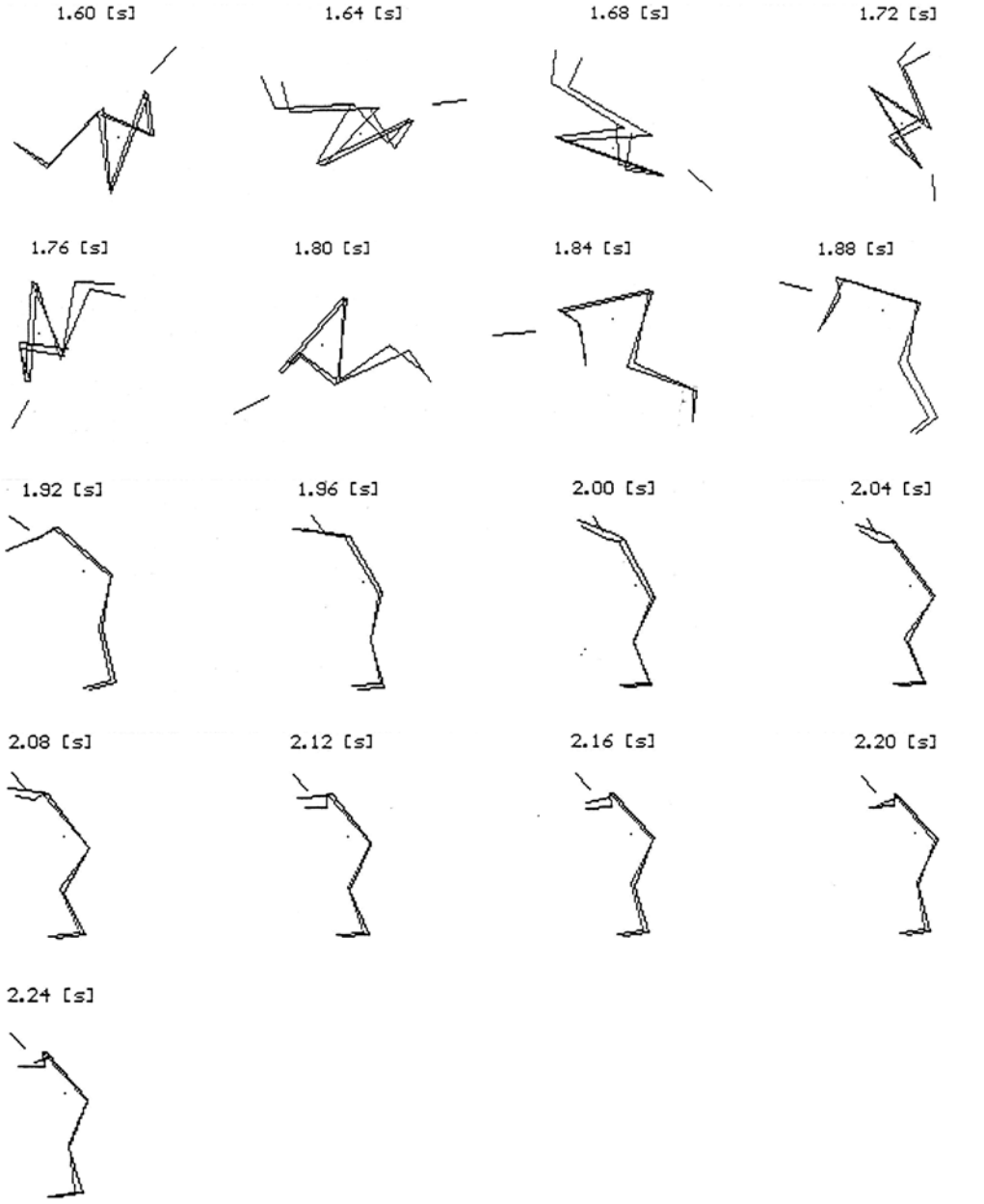


Figure 3. Kinogram of the triple salto backward tucked

Table 1. Biomechanical characteristics of the preparation phase and release phase

Variable/Phase	Body horizontal	Body vertical	Emphasised leg bending	Moment of release
Time [s]	0.28	0.60	0.72	0.92
Angle head –trunk	-89	-84	-75	-48
Angle upper arm- trunk [°]	209	186	131	38
Angle calf- trunk [°]	205	188	102	68
Angle calf -thigh [°]	179	172	153	66
Fxy on rings [G]	0.65	0.67	11.70	1.14
M on rings [Nm]	-271.94	-409.95	4617.00	210.32
Velocity BCG x axis [m/s]	-0.45	-0.22	0.47	0.14
Velocity BCG y axis [m/s]	-3.85	-0.19	4.52	3.57
Velocity BCG xy area [m/s]	3.88	0.29	4.55	3.58
Height BCG [m]	2.73	1.41	1.77	2.59

Legend: BCG-body centre of gravity

Table 2: Biomechanical characteristics of the flight phase and landing phase

Variable/Phase	End of the first salto	Maximum height	End of the second salto	First contact with mats
Time [s]	1.2	1.32	1.56	1.92
Angle head –trunk	-46	-31	-20	-5
Angle upper arm- trunk [°]	28	43	31	100
Angle calf- trunk [°]	45	43	25	122
Angle calf -thigh [°]	48	53	47	156
Angular velocity [°/s]	643	1000	1000	900
Velocity BCG x axis [m/s]	0.24	0.92	-0.20	-0.04
Velocity BCG y axis [m/s]	0.71	0.06	-2.59	-6.02
Velocity BCG xy area [m/s]	0.75	0.93	2.59	6.02
Height BCG [m]	3.16	3.18	2.75	1.07
Time from release to the first contact with mats [s]				1.00

The flight characteristics are in accordance with other authors (Čuk & Ferkolj, 2000) who were researching acrobatic elements on the floor (Table 3). The double salto backward stretched is included as by some authors (Arkaev & Sučilin, 2004, Gaverdovskij, 1987) and coaches (interviews with Vatkin (ex-national coach of the Belarus team and personal coach of Ivan Ivankov) and Hoffman (ex-national coach of East Germany) suggest the double salto stretched as a pre-element of the triple salto backward.

Table 3. Flight characteristics of some acrobatic elements and the triple salto backward tucked on rings

	Double salto backward stretched on floor (Čuk & Ferkolj, 2000)	**Triple salto backward tucked on floor (Čuk & Ferkolj, 2000)**	**Triple salto backward tucked on rings**
Fight time [s]	0.96	1.16	1
Degrees of rotation around x axis [°]	650	990	860
Average angular velocity [°/s]	677	853	860
Maximum height [m]	1.96	2.70	3.18

Compared to the execution of the triple salto backward tucked on the floor, we can state that on the floor a gymnast needs to fulfil more degrees of rotation than the take-off position on the floor and the release position on the rings differs by 130 degrees. The time of flight on the floor is slightly higher, but it produces a very similar average angular velocity. As the gymnast hangs on the rings at a height of 2.55 metres it is normal to have a higher maximum height; according to Krug (1992) the maximum height of the triple salto backward tucked from a high bar was 4.12m and the flight time was 1.36s, which are both much higher than on the rings. It is worth noting a gymnast's body centre of gravity on the high bar is circulating around the high bar, creating a curve around the bar, while on the rings the gymnast is moving forward, the rings are moving backward and the gymnast's body centre of gravity is moving vertically up and down. The gymnast's position during the flight is extremely tucked, there are very sharp angles in the hips and knees; the arm action is so hard that elbows are behind trunk. Fast leg bending is the most important task of a gymnast so as to make the angular velocity as high as possible. The average angular velocity is lowest in the first salto due to starting with bending (lowering the moment of inertia), during the second salto it is the highest (a minimum moment of inertia) and in the third salto because of the preparation for landing it is again lower (raising the moment of inertia due to stretching).

From a kinematic point of view, the position of the head in a vertical position differs from other easier swing elements (Čuk & Karacsony, 2002); the head is extremely extended as this creates an easier position for more angular momentum and force on the rings at beginning of the leg bending. The force on the rings is very high at 11.70G (and with a momentum of 4617Nm), while on the high bar values from Krug (1992) for the triple salto backward are commonly between 4.04G and 7.15G; according to Krug 7.15G is also the highest relative force on the high bar among all measured dismounts and release elements. Since based on practice we cannot imagine any more demanding element from the hang (rings, high bar, parallel bars) we can state the triple salto backward tucked on rings has the highest load on the hands where there is contact with the rings. One positive side is that a gymnast can use special safe guards on their hands, which significantly reduces the load on their fingers (Držaj, 2001). However, no one has yet calculated how safe guards reduce the grip forces. Despite safe guards, the triple salto backward on rings is so demanding that it requires extreme grip strength (if there is not enough, a gymnast can be pulled off the rings and an accidental fall can be very harmful). A similar pull off from the rings can happen if the safe guards are not in the proper condition. All of these are the main reasons for not performing a triple salto backward from the rings and, if we consider that gymnasts are

tired at the end of the rings routine, it is no wonder we do not see this dismount from the rings more often.

CONCLUSIONS

The triple salto backward involves:

- very high force (11.70 G) and momentum (4617 Nm) on the rings in the preparation phase;
- a very fast rotation around the x axis during the flight (860 °/s);
- a very small moment of inertia during the flight;
- extreme grip strength in the preparation phase and during the flight (pulling the knees as close as possible to the trunk);
- extreme strength and fast work of the trunk and leg flexors (receiving into and maintaining a tucked position); and
- extreme strength of the leg extensors (landing from 3.18m).

The biomechanical characteristics of the triple salto backward tucked are so demanding that, along with the double stretch salto backward with 3/2 or 2/1 turns, it can be regarded the most difficult swinging element on the rings.

REFERENCES

Arkaev, L.J., & Sučilin, H.,G. (2004). *Kak gotovit čempionov – teorija i tehnologija podgotovki gimnastov viššej kvalifikacii [How to make champions in gymnastics].* Moskva: Fiskultura i sport.

Colja, I. (1995). *Računalniški program za izračun sil pri kroženju [Computer software for the calculation of forces during circling].* Ljubljana: Fakulteta za šport.

Čuk, I., & Ferkolj, M. (2000). Kinematics analysis of some backward acrobatic jumps. In: Y. Hong & D.P. Johns (eds.), *Proceedings of XVIII international symposium on biomechanics in sport, Hong Kong* (pp.36-38). Hong Kong: The Chinese University of Hong Kong.

Čuk, I., & Karácsony, I. (2002). *Rings: methods, ideas, curiosities, history.* Norman: Paul Ziert & Assoc.

Držaj, S. (2001). *Tehnika in metodika trojnega skrčenega salta nazaj s krogov [Techinque and methodic of the triple salto backward tucked on rings].* Unpublished bachelor's thesis, Ljubljana: Fakulteta za šport.

FIG (1996). *Code of Points – Artistic Gymnastics for Men.*

FIG (2000). *Code of Points – Artistic Gymnastics for Men.*

FIG (2006). *Code of Points – Artistic Gymnastics for Men.*

FIG (2009). *Code of Points – Artistic Gymnastics for Men.*

Gaverdovskij, J.K., (ed.). (1987). *Gimnastičeskoe mnogobore mužskie vidi [Gymnastics all around – Men].* Moskva: Fiskultura i sport.

Gregorka, B., & Vazzas, J. (1984). *Razvoj telovadnega orodja krogov [Development of gymnastics apparatus].* Begunje: Elan.

Krug, J.(1992). *Biomechanische Analyse von Flugelementen und Abgangen am Reck zu den Europameisterschaften der Maenner 1992 in Budapest.* Leipzig: Institut fuer angewandte trainingswissenschaft – Fachgruppe technikorientierte Sportarten.

Prassas, S. (2008). *Biomechanical Research in Gymnastics: What is Done, What is Needed.* http://www.coachesinfo.com/index.php?option=com_content&view=article&id=182:gymnastics-isbs-biomechanical&catid=158:generalcoaching&Itemid=271, accessed 9 December 2010.

Goehler, R. (1989). *Geschichte der Turngeraete [Development of gymnastics].* Herausberg: Rudolf Spieth.

Sušanka, P., Otahal, S., & Karas, V. (1987). *Zaklady biomechanicky telesnyh cvičeni [Biomechanics of human movement].* Praha: Universita Karlova.

Winter, D.A. (1979). *Biomechanics of Human Movement.* New York: J. Wiley and sons.