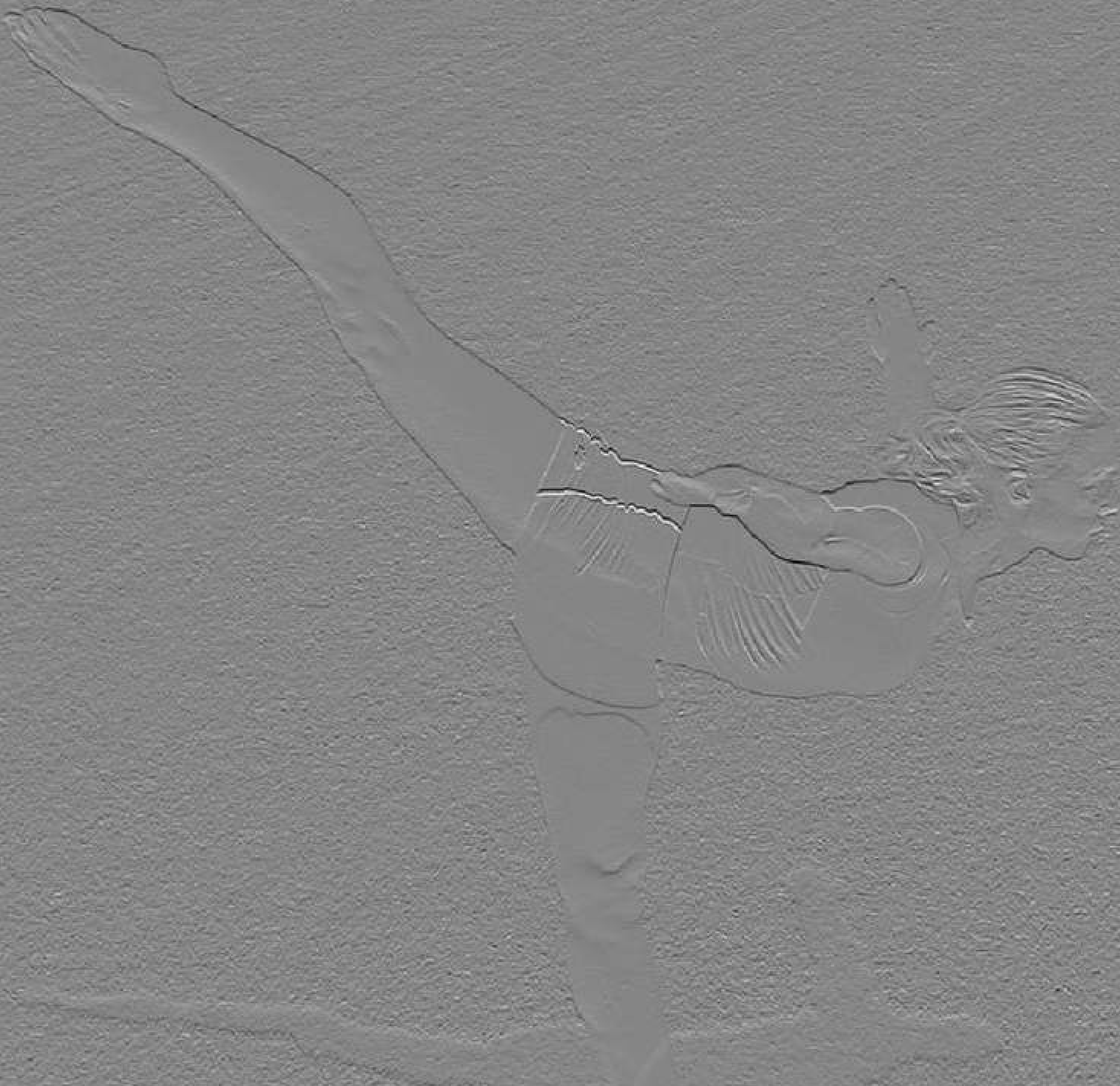
SCIENCE OF GYMNASTICS JOURNAL



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Science of Gymnastics Journal (ScGYM®)

Science of Gymnastics Journal (ScGYM®) is an international journal that provide a wide range of of scientific information specific to gymnastics. The journal is publishing both empirical and theoretical contributions related to gymnastics from the natural, social and human sciences. It is aimed at enhancing gymnastics knowledge (theoretical and practical) based on research and scientific methodology. We welcome articles concerned with performance analysis, judges' analysis, biomechanical analysis of gymnastics elements, medical analysis in gymnastics, pedagological analysis related to gymnastics, biographies of important gymnastics personalities and other historical analysis, social aspects of gymnastics, motor learning and motor control in gymnastics, methodology of learning gymnastics elements, etc. Manuscripts based on quality research and comprehensive research reviews will also be considered for publication. The journal welcomes papers from all types of research paradigms.

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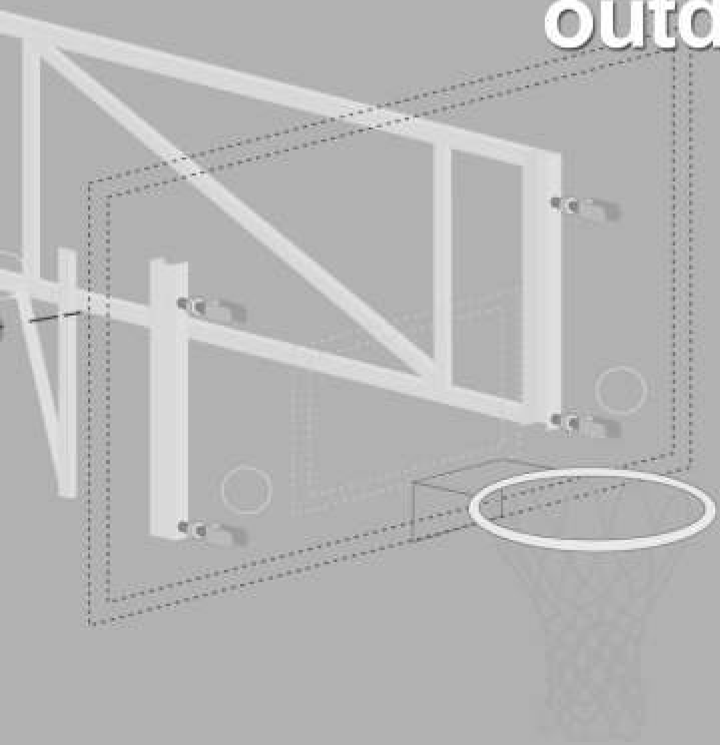

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EDITORIAL

Dear friends,

In front of you is a new journal with an easy name to remember, the Science of Gymnastics Journal. It is a journal, as the name says, dedicated to gymnastics.

When I checked the keyword 'gymnastics' on the Web of Science (WoS, as of 14th July) I learned that throughout the history of WoS (since 1970), 'gymnastics' has featured in 410 journals. The top four journals are the MEDICINE AND SCIENCE IN SPORTS AND EXERCISE with 29 published articles, the AMERICAN JOURNAL OF SPORTS MEDICINE with 21 articles, CLINICS IN SPORTS MEDICINE and the JOURNAL OF SPORTS MEDICINE AND PHYSICAL FITNESS with 20 articles each. The top 25 journals have published 344 articles and all of them together have published 885 gymnastics-related articles. As the WoS was established in the USA, most of the articles are in English (85%), followed by German (6.8%) and French (3.9%). There are also a few articles published in Italian, Russian, Portuguese, Spanish and Turkish respectively.

We decided to use English as the main language, but will also publish articles in the writer's mother language should he or she wish so.

In 1970, when the WoS was established, there were no articles about gymnastics; this number shot up to 64 articles in 2007. The WoS includes writers from 46 countries, most of them from the USA, France, England and Germany. It is interesting to note that there are precious few articles from the former Soviet Union, the whole eastern block and Asia. This is in stark contrast with results achieved in gymnastics at Olympic games and world championships.

The gymnastics community has wide interests; gymnastics itself can be approached from a range of aspects. There is an enormous field of research, spanning from history and medicine to biomechanics. Subjects can cover newborns and elderly, and everyone in-between; research can focus on absolute beginners or on top athletes winning world champions. There is a wide spectrum of disciplines, including artistic gymnastics, acrobatics, rhythmic gymnastics, sports aerobics etc.

Gymnastics is the key word to all of us. The Science of Gymnastics Journal wishes to be a meeting point for all those who are interested in research and want to share their knowledge with others. Some issues are so specific they cannot be published anywhere else, for example, case studies, such as biomechanical characteristics of the Pegan salto on the high bar. The Science of Gymnastics Journal will be more than pleased to publish such case studies on top gymnasts.

The first issue of our journal brings six articles. Their writers come from four countries. They cover a wide range of topics, including biomechanics, motor learning, diet, performance characteristics and terminology.

As we want to be read by researchers, coaches, judges, gymnasts, parents, students and gymnastics fans we will be available on www.scienceofgymnastics.com 24/7, free of charge.

Thank you for reading, I am looking forward to your comments and your articles,

Ivan Čuk
Editor-in-Chief

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TKACHEV SALTO ON HIGH BAR

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Original research article

Abstract

With the new FIG Code of Points for men (2006) based on the philosophy of open ended difficulty score, point advantages have been given, again, to those who are in search for and willing to perform new elements. Each element in the Code of Points can be developed by changing its start and its final position, the start and the final grip with the apparatus, the body position during the element, by adding a flight phase or a rotation around the frontal, the longitudinal or the sagital axis. The Tkachev is quite an old release element (approximately 40 years old) on high bar. In line with the knowledge available to us today, we have been looking into the possibility of performing the Tkachev salto. Following series of biomechanical analysis with consideration of the gymnast's safety, we calculated that the Tkachev salto could be performed by those gymnasts who can perform the straight Tkachev with a high amplitude. Gymnast who will be able to perform the Tkachev salto at a major competition will enter the gymnastics history and have huge chances of wining the most prestigious competitions.

Key words: *artistic gymnastics, biomechanics, new elements, Tkachev salto*

INTRODUCTION

During the seventies and eighties of the 20th century, the International Gymnastics Federation (FIG) Code of Points (1980) awarded gymnasts who performed new elements by giving them an advantage of 0.2 points for originality and 0.2 points for courage. From that time Tkachev, Gienger, Jaeger, Delchev, Kovacs, Gaylord and others competed on high bar (Goetze and Uhr, 1994). In the nineties those advantages were removed from the code and a number of the newly introduced elements were dropped. From 2006, the FIG Code of Points introduced a new philosophy of an open ended difficulty score which rewards gymnasts for performing very difficult elements. With the performance of super new element gymnasts also makes his name popular among judges what gives him non material (in points) advantage. The Tkachev element is described by hang with overgrip swing frontways, hecht backward with split legs into hang with overgrip swing backways. When introduced it was a huge attraction as during the flight the gymnast attraction as during the flight the gymnast travels backward over the bar with a forward body rotation (around the sagital axis). The originally element was designed in the USSR originally element was designed in the USSR laboratories by Gaverdovskij (1987) and was first performed in the late sixties by the soviet gymnast, Pitomcev, at national competitions. However, it was first performed on the international by another Soviet gymnast, Vladimir Tkachev, in Vilnus during the European championships in 1977. Soon afterwards a piked version was performed by Tkachev himself and in 1988 Valerij Ljukin (USSR) performed a straight Tkachev and a straight Tkachev with 1/1 (360 degrees) turn (fig.1., fig.2., fig.3.). Since then, the Tkachev family of elements has remained unchanged.

The Tkachev can be divided into four phases: preparational phase (from handstand to hang in vertical position), release phase (from hang up to the release), flight phase (airborne phase), and re-grasp (the moment of re-grasping high bar).

Each phase has the following main biomechanical characteristics. In the first phase (traveling downwards), the gymnast accumulates as much energy as possible, part of this energy is also stored in high bar.

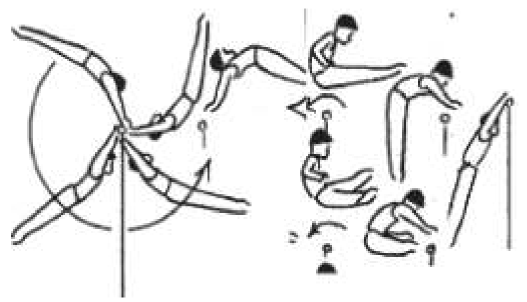

Figure 1. *Tkachev, piked Tkachev (FIG, 2006)*

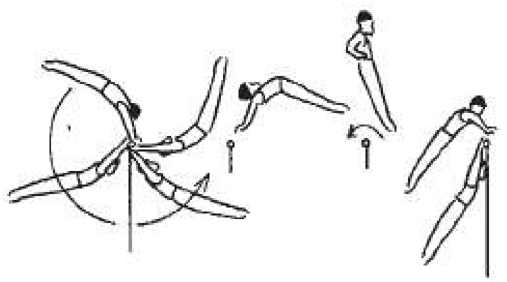

Figure. 2. *Stretched Tkachev (FIG,2006)*

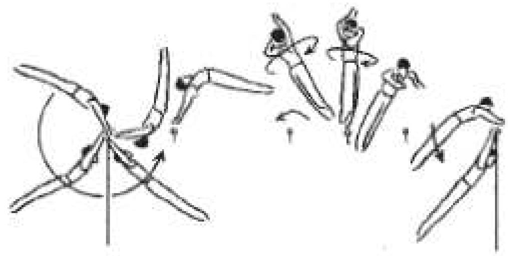

Figure 3. *Stretched Tkachev with 1/1 turn (FIG, 2006)*

In the second phase (traveling upwards), the gymnast tries to save as much energy as possible and to split this energy into the needed proportion between translator and rotational energy for the next phase (Arampratzis and Brueggemann, 1999). In the flight phase angular momentum is constant during flight to perform the element safely, the parabolic trajectory of the body's center of gravity has to be optimal (in x axis), not too far from the high bar (followed by a fall), nor too close (resulting in a fall on the bar or a seriously slowed movement hindering the continuation of the exercise), to re-grasp the bar with the body position and energy to continue the exercise without mistakes. The aim of a higher trajectory of the body's center of gravity in y axis during flight is to extend the time of flight and the aesthetic view for the judges with a bigger amplitude.

Researchers from all over the world have done extensive investigations on Tkachevs. Their results will be of importance in determining whether a Tkachev salto is possible or not according to the release, flight and re-grasp characteristics. Qian, Cai, Tang and Zhou (1987) published their case study about a straight Tkachev performed by gymnast Zhao Zhinqiang. They reported an optimal moment of release with a 41.8 degree angle between the x-axis and the body center of gravity, with a body center of gravity vertical velocity of 4.18 ms^{-1}; after the release they reported an angular velocity of 2.58 rad/s (147.8^{o} s^{-1}). Krug (1992) reported the following results after analysing ten regular Tkachevs: average angular momentum of 24 kgm^2 s^{-1}, minimum 18 kgm^2 s^{-1} and maximum 29 kgm^2 s^{-1}, and an average load to apparatus of 5.3 G-force with a maximum load of 6.1 G-force. Yilmaz, Brueggemann and Cheetham (1993) reported the following data for the original Tkachev: body center of gravity vertical velocity at the moment of release 2.44 ms^{-1} (standard deviation = 0.23), body center of gravity horizontal velocity of -2.40 ms^{-1} (standard deviation = 0.32). Takeda, Tuchiya and Shiraishi (1993) reported the following data for the Stretched Tkachev: at the moment of release the hip angle is 212 degrees and the shoulder angle is 190 degrees, while hip velocityis 4 ms^{-1}. Čuk, Piletič (1995) reported the following data for a case study of Ivankov's straight Tkachev: horizontal velocity at release 2.54 ms^{-1}, vertical velocity at release 2.52 ms^{-1}, total velocity of body center of gravity 3.59 ms^{-1}, total velocity of body center of gravity 3.59 ms^{-1}, and angular velocity of 229.3°/s^{-1}. Arampatzis and Brueggemen (2001) reported the following data for the original Tkachev (numerus = 20): body center of gravity horizontal velocity 1.97 ms^{-1} (standard deviation = 0.38), body center of gravity vertical velocity 3.08 ms^{-1} (standard deviation = 0.44), angular momentum at release 33.39 kgm^2 s^{-1} (standard deviation=4.55). Atiković (2006) reported the following flight times for Tkachev's performed at the European Chamiponships 2005 in Debrecen: traditional Tkachev mean-0.68s, max-0.80s, min-0.56s ; piked Tkachev mean-0.67s, max-0.72s, min-0.64s; stretched Tkachev mean-0.70s, max-0.76s, min-0.64s. Research showing the minimum flight time for a 540 degree salto tucked (Gaylord salto) on uneven bars was reported by Mclaughlin, Geiblinger, Morrison (1995). Kerwin, Irwin and Samuelson (2007) obtained from the 2000 Olympic Games angular momentum for ten straight Tkachev 34.1 (standard deviation = 7.6) kgm^2 s^{-1}. Čuk and Colja (1996) defined a general model for developing new elements in gymnastics. According to data collected, we thought of an idea for a new element: a Tkachev salto (fig. 4).

The aim of our investigation is to discover under which conditions a Tkachev salto can be performed safely.

METHODS

Methods of analyzing data are mostly logical and theoretical with acknowledgement of previous research results with similar elements of body position and movement. For calculating physical values we used Newton's physics, subsequently we modeled and adjusted those physical values in order to find a combination of them that can be performed in practice. For calculating position of body center of gravity we used Dempster's body model (by Winter 1979) and Ivan Ivankov's (Belarus) basic anthropometric data (body height 1.60 m, and body mass 57 kg). For calculating the moment of inertia of the body we used Petrov and Gagin's (1974) cylindrical model. As a basis for calculations of other physical values we used data of the straight Tkachev from Ivan Ivankov (Čuk and Piletič 1995); data from Ivan Ivankov was obtained in 1994 during the European championship.

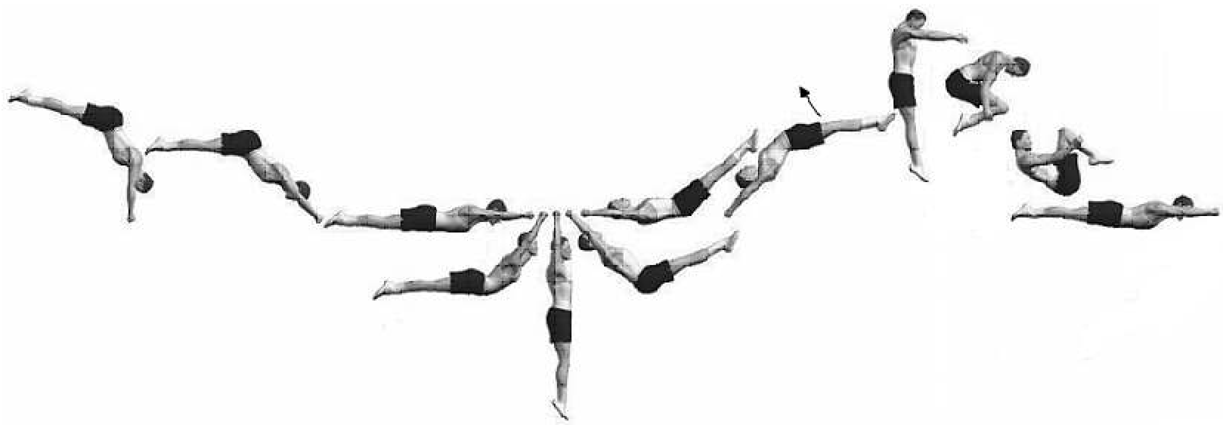

Figure 4. *Idea of Tkachev salto*

The year of 1994 was the best year ever for Ivankov as he won the all around World and European title; he was 18 years old and was in the best condition of his sporting life From 1996 he experienced injuries and was never in such excellent sporting form again.

RESULTS AND DISCUSSION

Results show that a Tkachev salto can be safely performed under the conditions which follow. When performing a forward salto the gymnast's head (or any other part of the body) must be far away from the bar for the safety reasons. For the reason of safety and the reason of an appropriate moment of inertia, we chose the following body position with the following angles between body parts: angle between trunk and head 65°, hip angle 60°, and knee angle 70° (fig. 5.). Tkachev salto tucked was chosen because of the ease of motor control and motor learning. Most of the handspring saltos on vault and floor have combination arched body/tucked body, split legs require an additional operation and muscle group to activate and control. This tucked position is still within FIG rules without any deductions (FIG rules define a tucked position as angles are smaller or equal to 90 degrees in the hip and knee joint) and also has a lower moment of inertia.

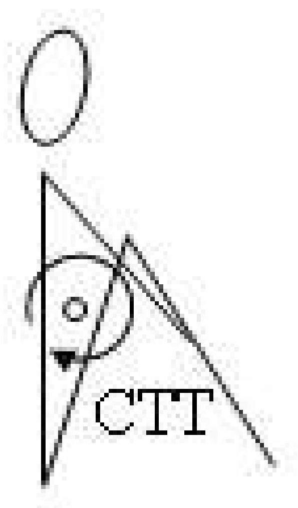

Figure 5. *Ideal tucked position for Tkachev salto*

The calculated length and mass of body parts by Dempster (by Winter, 1979) for Ivan Ivankov (h = 1.6m; m = 57kg) are: head with neck (length (m) = 0.291, mass (kg) = 4.62); trunk (0.541m, 28.33kg); upper arm (0.244m, 3.19kg), lower arm with hand (0.23m, 2.51 kg); thigh (0.392m, 11.40 kg); calf with feet (0.456m, 6.95kg). In the defined tucked position the body center of gravity is 0.07m in x axis and 0.29m in y axis (0.0 is in hip joint); distance between head and body center of gravity = 0.52m, while the distance between feet and body center of gravity is = 0.51 m. For the chosen position we calculated the moment of inertia for rotation around the frontal axis by the suggested formula $J = ml^2/12$ of Petrov and Gagin (1974) for a tucked position, position at release and position at re-grasp: for height l = 0.804m of Ivankov in tucked position $J_{tucked} = 3.076\ kgm^2$ *(tucked position);* for height (length) l = 1.647 m of Ivankov at release $J_{release} = 12.885\ kgm^2$ *(arched position with arms upward)*, for height (length) l = 1.247 m of Ivankov at regrasp $J_{regrasp} = 7.386\ kgm^2$ *(tucked position with arms upward).* Time of flight is determined by 540 degrees rotation forward. Full rotation can be divided into three phases: arched body releases high bar and then rotates until it reaches tucked position, rotating tucked body, opening and re-grasp. Čuk and Karacsony (2004) note the fastest bend from stretched or arched body into full tucked position is 0.24 seconds. We will accept this time as the time required for bending to calculate the angle of rotation, we are presuming linear change of body length when calculating the moment of inertia. Čuk and Piletič (1995) reported for Ivankov during a stretched Tkachev that the angular velocity when releasing the high bar was $229.3°/s^{-1}$. During the flight, angular momentum (the product between moment of inertia and angular velocity) is constant and we can calculate when the required 540° angle of rotation will be fulfilled. We calculated the angular momentum for Ivankov's stretched Tkachev by the formula: $\Gamma_{during\ flight} = J_{moment\ of\ release}\ \omega_{moment\ of\ release}$ = constant = 51.56 Nms (table 1.). The calculated angular momentum for the straight Tkachev seems quite high. Krug's (1992) measurement for a regular Tkachev's maximum angular momentum was 29 Nms. Even though our estimation of an angular momentum of 51.6 kgm2s-1 is too high, we can say that Kerwin *et al* (2007) also obtain similar high end values (34, 1 + 7, 6 * 2, 33 standard deviation) = 51.808

kgm2s-1. That means that 1% of those who are performing a straight Tkachev can also perform a Tkachev salto which gives this element an extremely high difficulty value and still proves that it is possible. The angle of rotation in the first 0.24 seconds is calculated in steps by each 0.01 second. In the first 0.24 second, a gymnast will finish 116.46 degrees of rotation (table 1.).To fulfill 540 degrees the gymnast has to rotate another 424.54 degrees. After 0.24 second the gymnast in tucked position has a constant angular velocity of 962.23°/s. This angular velocity is in accordance with Krug (1993), where triple saltos performed on different apparatus can reach an even higher angular velocity than 1000°/s. Preparation to assume the proper position for re-grasp (tucked with arms upward) can be performed by the gymnast in half the time of tucking, as the gymnast has only to move arms upward, again we presumed linear change of gymnasts length. Angle of rotation in the last 0.12 seconds is calculated in steps of 0.01 second. In the last 0.12 second, the gymnast will finish 71.69 degrees of rotation (table 2.). The whole angle of rotation of tucking and opening is: 116.46° + 71.69° = 188,15°. To fulfill a 540° salto the gymnast has to rotate another 351.85 degrees. We calculated the time needed to fulfill the following angle by the formula: angle = ω*t ; t = angle/ω = 351.85° / 962.23°s^{-1} = 0.36 s, therefore the whole time to complete a Tkachev salto is: time of tucking + time rotating

Table 1. *Change of angle of rotation in the first 0.24 second*

Step	t (time) (s)	Change of height (m)	$J=ml^2/12$ (kgm^2)	ω= Γ/J (° s^{-1})	Γ=Jω (Nms)	Angle= ω*0,01s (degrees)	**Total angle (degrees)**
1	0	1.65	12.88	229.3	51.56	0	0
2	0.01	1.61	12.34	239.4		2.39	2.39
3	0.02	1.58	11.81	250.19		2.5	4.9
4	0.03	1.54	11.29	261.72		2.62	7.51
5	0.04	1.51	10.78	274.06		2.74	10.25
6	0.05	1.47	10.28	287.31		2.87	13.13
7	0.06	1.44	9.8	301.53		3.02	16.14
8	0.07	1.4	9.32	316.84		3.17	19.31
9	0.08	1.37	8.86	333.34		3.33	22.64
10	0.09	1.33	8.41	351.17		3.51	26.16
11	0.1	1.3	7.98	370.47		3.7	29.86
12	0.11	1.261	7.55	391.40		3.91	33.77
13	0.12	1.226	7.13	414.16		4.14	37.92
14	0.13	1.190	6.73	438.96		4.39	42.31
15	0.14	1.155	6.34	466.06		4.66	46.97
16	0.15	1.120	5.96	495.74		4.96	51.92
17	0.16	1.085	5.59	528.36		5.28	57.21
18	0.17	1.050	5.24	564.31		5.64	62.85
19	0.18	1.015	4.89	604.05		6.04	68.89
20	0.19	0.980	4.56	648.14		6.48	75.37
21	0.2	0.945	4.24	697.25		6.97	82.34
22	0.21	0.909	3.93	752.15		7.52	89.87
23	0.22	0.874	3.63	813.80		8.14	98.00
24	0.23	0.839	3.34	883.36		8.83	106.84
25	0.24	0.804	3.07	962.23		9.62	116.46

completely *tucked + time of opening = 0.24s + 0.36s + 0.12s = 0.68s***.** From Atikovć (2006) studies better gymnasts performing a straight Tkachev at the European championship of 2005 would also have enough time to perform a Tkachev salto. For calculating the trajectory of body center of gravity in x and y axis we were modeling the position of the body in the release phase and in the moment of re-grasp. To calculate body center of gravity at the moment of release we used a three segment body model (arms, trunk with head, and whole leg), for the moment of regrasp we used a four segment body model (arms, trunk with head, thigh, and calf with feet). Reasons why we chose different models are practical and common for gymnastic performance of the Tkachev; during release the arms and legs are stretched, while during re-grasp we presumed that the gymnast should stay in tucked position until re-grasp in order to have enough rotation. By modeling different release and re-grasp positions we found the best fit with the following positions as shown in figure 6. Release position has the following data (center of high bar is 0.0) angle x axis – arms 40°, x-axis – trunk 0° and x axis – legs 340°, and re-grasp angle x axis – arms 180°, x-axis – trunk 180°, x axis – thigh 330°, x axis – calf with feet 240°. While the release position can be quite different, with adjusted vertical and horizontal velocity, the re-grasp position is much more determined and this is what makes the new element very difficult. The body center of gravity has to be close to the high bar height, far enough from the high bar to re-grasp with shoulders at 180 degrees. Late re-grasps which are usual for the original Tkachev or for some other release elements are dangerous as the gymnast is too close to the bar during salto (fig. 6.).The body center of gravity horizontal velocity during the flight is constant and is therefore calculated by the formula: ($s_{xrelease}$ – $s_{xregrasp}$) / time of flight = (0.808m-(-0.784m)) / 0.68 s^{-1} = 2.34 ms^{-1}. For the calculation of body center of gravity vertical velocity we were modeling vertical velocity from 2.00 ms^{-1} and calculate time of uprising ($t_{uprise}=v_{yrelease}/g$; $g=9.81ms^{-2}$), reached height ($h_{max}=h_{release}+gt_{uprise}^2$), whole height of falling ($h_{fall}=h_{max}-h_{regrasp}$)(difference between re-grasp position and maximum height), time of falling (t_{fall}=sqrt(h_{fall}/g) and whole time of flight ($t_{total}= t_{uprise}+ t_{fall}$). For the whole flight time of 0.68

Table 2. *Change of angle of rotation in last 0.12 second*

Step	t (time) (s)	Change of height (m)	$J=ml^2/12$ (kgm^2)	$\omega=\Gamma/J$ ($^o s^{-1}$)	$\Gamma=J\omega$ (Nms)	Angle= ω*0,01s (degrees)	**Total angle (degrees)**
1	0	0.8	3.07	962.23	51.56	0	0
2	0.01	0.84	3.36	879.6		8.8	8.8
3	0.02	0.88	3.66	807.17		8.07	16.87
4	0.03	0.92	3.98	743.34		7.43	24.3
5	0.04	0.95	4.3	686.79		6.87	31.17
6	0.05	0.99	4.64	636.45		6.36	37.53
7	0.06	1.03	5	591.45		5.91	43.45
8	0.07	1.062	5.361	551.06		5.51	48.96
9	0.08	1.099	5.741	514.67		5.15	54.11
10	0.09	1.136	6.133	481.77		4.82	58.92
11	0.1	1.173	6.538	451.93		4.52	63.44
12	0.11	1.210	6.955	424.78		4.25	67.69
13	0.12	1.247	7.386	400.00		4.00	71.69

second (according to release and re-grasp position) body center of gravity vertical velocity is 2.77ms^{-1}, total body center of gravity velocity in xy at release is 3.62 ms^{-1} (vertical, horizontal and xy velocity are lower than published in previous research). The minimum distance between BCG and high bar is 0.59m which means that the gymnast's body parts are a minimum of 0.07m away from high bar at any time (fig. 7.).

CONCLUSION

The high demands of performing a Tkachev salto can be achieved by excellent gymnasts who can perform a straight Tkachev with a very high amplitude. However, the new element is extremely difficult to perform as its basic conditions are: position of release requires very good flexibility of the arms and trunk (angle x axis – arms 43, arms-trunk 223, trunk - legs 200); a very good physical preparation as a tucking time of 0.24s can be only be performed by the best prepared gymnast; the time of flight has to be at least 0.68s which should not be a problem for the gymnasts who can perform a straight Tkachev; vertical velocity should be as high as possible, but minimum safe velocity is 2.77 ms^{-1}, as this gives the gymnast more airborne time and a higher distance from the high bar (in this case the gymnast's position can also be more open); one problem which has yet to be analysed is how to preserve angular momentum during release. All the calculated data for a safe Tkachev salto; time of flight; vertical, horizontal and total velocity at release; body angles at release and re-grasp; angular momentum during flight; and the distance of the gymnast from the high bar, are equal to or lower than other comparative researches. As maximum known load to apparatus (at rings, at the gymnasts vertical position in hang performing triple salto backward tucked) is 13G (Čuk, Karacsony, 2002), we can conclude that the production and preservation of angular momentum during the preparation phase until the release phase should be solved. As gymnasts can produce even higher biomechanical values than those needed for a Tkachev salto, we can conclude that a Tkachev salto can be accomplished, and will probably, in the near future, be performed at competitions.

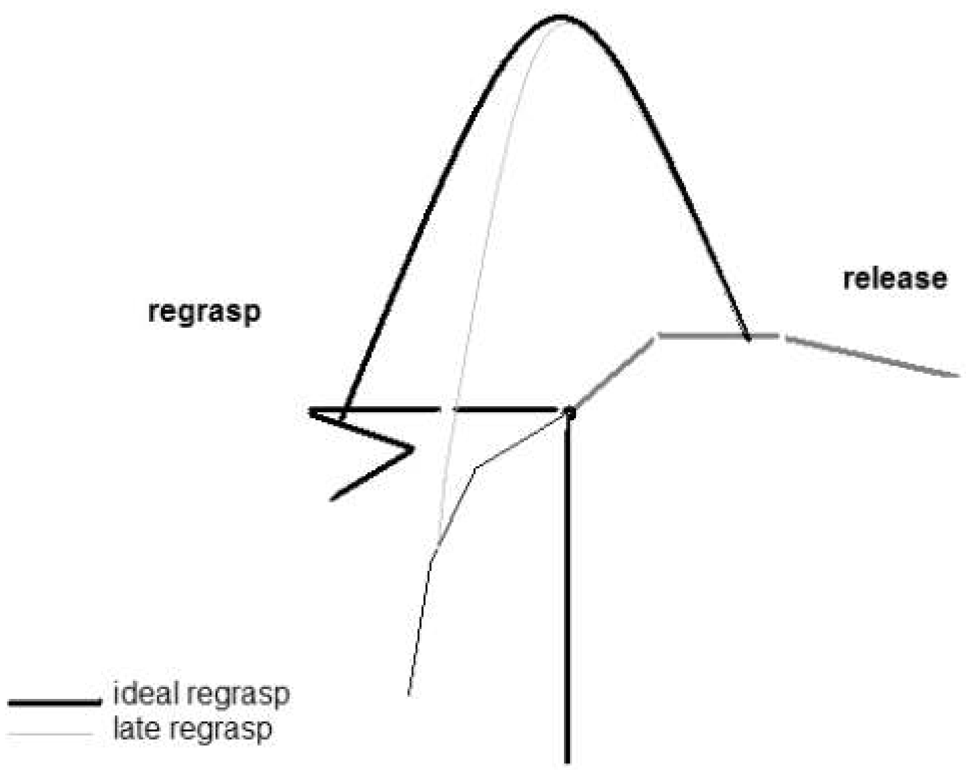

Figure 6. *Body position at release and regrasp*

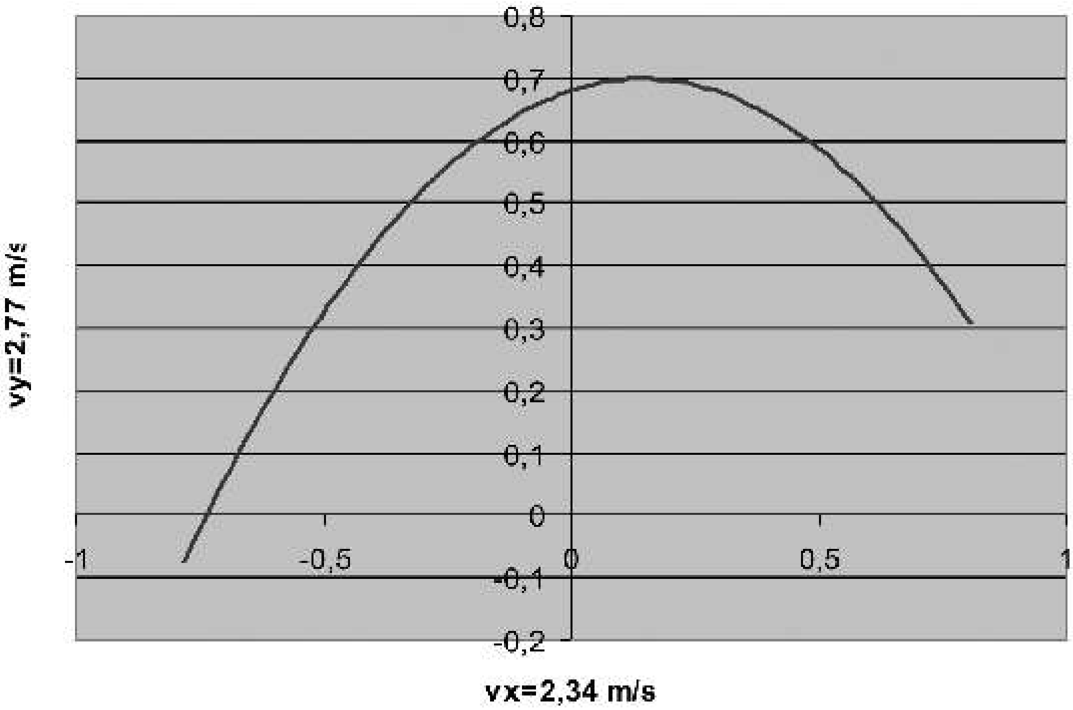

Figure 7. *Pathway of body center of gravity in x,y axis (m)(0,0 = high bar)*

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A CASE STUDY OF A BODY WEIGHT CONTROL PROGRAMME FOR ELITE CHINESE FEMALE GYMNASTS IN PREPARATION FOR THE 2008 OLYMPIC GAMES

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Case report

Abstract

For top level female gymnasts , effective body fat reduction is a long-term process, often resulting in various issues; how to keep the physical fitness at an optimal level? How to control the amount of training to improve skill and performance? This report presents a case study of a successful weight-loss program used by the Chinese National Gymnastics Team when preparing for the 2008 Olympic Games.

Key words: *body weight control, Olympic Games, elite gymnastics*

INTRODUCTION

Olympic level female athletes experience a great deal of stress before competing (Pensgard, 1997), which can result in negative physical and psychological changes (Wegner, 2000) such as an irregular menstrual cycle (Dueck, Manore, & Matt, 1996); bodyweight increase; lack of motivation for training; lowered confidence and depression (Ardila, 2006).

This study reports the case of a 16-year-old female gymnast in the Chinese National Team who was involved in these circumstances prior to the 2008 Olympic Games. The balance of energy input (food intake) and energy output (physical activity) is key to body-weight management. In order to reduce body weight the study subject reduced their food intake while maintaining regular exercise for 2 weeks (period 1: June 13-23, 2008). During this period the energy input from food was 1,000 Kcal per day, and the volume of liquid was 800-1.000 ml each day. She ate a snack made from high fat and high-sodium, full flavor, low moisture content and the small quantity after the daily training short before sleep in the late evening. However, this led to an increase rather than desired decrease in body weight (520 grams); of this 453 grams were fat (Table 3). After increasing her body weight she lost motivation for training and became depressed. At this point she sought professional assistance. A comprehensive program for losing body weight and improving her motivation was needed. Such a program should include both a physiological aspect and a psychological aspect (Rushall, 1989). For a successful bodyweight management program we had to deal with several factors such as losing body weight, finding the optimal bodyweight for the subject while maintaining skill and performance level, and regaining self-confidence. The aim of this article is to present a detailed approach to body weight management in elite gymnasts.

METHODS

The subject was a 16-year-old female gymnast in the Chinese National Gymnastics Team preparing for the 2008 Olympic Games. The body mass and body height of the subject was measured using weighing scales (Inco, Ambala, India, Model No. 4516 PXL) fitted with a height measuring stand.

BMI was calculated using the following formula: weight / the square of height. Body fat was measured using the GE Lunar Prodigy DF+301772 (GE Lunar, Madison, WI). The intervention program lasted for four weeks (June 23 – July 21, 2009) and consisted of 6 aspects that are explained in detail in Table 1.

Timing and quantity of food and liquid intake during the intervention period for the subject is presented in Table 2. The subject also took the following vitamins and minerals on a daily basis: vitamin A (780 mg), vitamin C (160 mg), thiamin (1.1 mg), riboflavin (1.6 mg), niacin (15.6 mg), calcium (900-1000 mg),and iron (15.8 mg) (note: all values are mean).

Table 1. *Description of the intervention program*

Aspect	**Description**
1. Cooperation with coach	Close communication was established between the program designers and the coach (Anthanasios, 2005). They met a couple of times each day (Cote, & Salmela, 1996). Therefore, the program designers had detailed information of the amount of daily training and daily activity and they precisely calculated daily energy consumed (Carta et al, 1998). Food intake was based on this energy consumed.
2. Diet regulation	To calculate precise energy intake (Bajerska, Jeszka, & Kostrzewa, 2003), a Personal Health Status Questionnaire* and a Daily Nutrient Intake Record** was used.
3. Adjust physical activity besides daily training	The athlete gained fat during period 1 (June 13-23, 2008) when she was in control of managing her her body weight. To help her lose weight some physical activities such as Pilates, Yoga, Dancing, and Meditation were added to the training program (La Forge, 2009). These activities were selected because of there effectiveness in burning calories, furthermore the participant enjoyed doing these activities (Berger, Pargman, & Weinberg, 2002). This non-training physical activity not only helped to achieve an ideal body weight, but also improved the athlete's self-confidence (Gallagher, Jakicic, Napolitano, & Marcus, 2006).
4. Use "true" body weight indicator to record the athlete's courage and encourage the athlete	The athlete did not fully understand the difference between body weight and body fat (Weier, 1997) and was therefore stressed when her body weight increased. Use the "true" body weight indicator to record the athlete's courage and encourage the athlete.
5. Combat the athlete's depressive condition	The athlete associated body weight control with feeling stressed. At the beginning of the program the athlete expressed her depression and disappointment (Barnes, Vogel, Beck, Schoenfeld, & Owen, 2008), she needed help to overcome these stressful feelings. Besides the additional physical activity mentioned above, the athlete took part in music therapy (Saalfield, 2008) four times a week. Communicational psychological technique was conducted to improve the relationship between the coach and the athlete by helping each relate to the other more effectively, thus improving the atmosphere in training (Silverman, 2009).
6. Assessments and evaluations used to prevent the athlete from "overtraining"	Quantitative analysis of EEG and statistical mapping techniques were used in the system as early as possible in phase I in order to show the central effects of a new compound concluded in her body-weight control system (response relationships or time/efficacy potential, brain bioavailability, effects on vigilance, et.)

* Personal Health Status Questionnaire. This Questionnaire provided detailed information about personal medical history, family history, personal training history, personal life-style, including eating-habits.

** Daily Nutrient Intake Record. The athlete recorded a daily nutrient intake and submitted this record to a weight manager. The weight manager was a special coach whose responsibility was to analyze the record and to calculate a precise amount of daily nutrients intake for the athlete. The manager and the athlete kept close communication that made the athlete feel comfortable about the food intake (Filaire et al, 2002).

Table 2. *Nutrition and beverage intake per day in the intervention period*

TIME	FOOD (g)	Liquid (ml)
6 am	50.0	400.0
8 am	250.0	300.0
10 am	100.0	250.0
12 am	550.0	200.0
15 pm	250.0	350.0
18 pm	400.0	250.0
20 pm	0.0	300.0
Total	**1600.0****	**2050***

*Liquid intake: Stover et al, 2006)
** - of total 1600 Kcal 68% were carbohydrate, 20% were proteins and 12% were fats

RESULTS

Over 28 days the participant lost 840 grams of body weight, of this 356 grams were fat (Table 3). The participant achieved the optimal balance between fitness and body weight. She developed a desirable mental condition for competition and managed to achieve a respectable result at the 2008 Olympic Games.

DISCUSSION

This is a case report of a successful body weight management program for an elite woman gymnast in the Chinese national gymnastics team who achieved a top level result at the 2008 Olympic Games.

It is of crucial importance to achieve the optimal body weight and body compositionto compete at the highest level in gymnastics, however this is difficult to achieve because of the unique characteristics required for this sport.

The gym-nastic performance at Olympic championships is influenced by physical factors (Stark, & In, 1991), such as body weight, body composition; and psychological factors, such as self-confidence, motivation, skill and event. Therefore, a body weight management program should be comprehensive. The following aspects were considered in our program.

1. Reduce body fat before the Olympic Games maintaining an optimal weight is a an ongoing process for elite gymnasts. Although almost always lean, elite gymnasts aim to lose a little more body fat prior to the Olymnpic Games in order to gain even the slightest advantage.

Balance is important for gymnastic athlete because if their bodyweight is too high then their power, speed, agility, flexibility and balance may be compromised (Ackland, Elliott, & Richards, 2003), however, if their body weight is too low, they will not have enough muscle to produce muscular strength required for power, speed, agility, flexibility, and balance. Achieving this optimal condition can be difficult, particularly if the gymnast is left to achieve it themself. Diet management (Schuit, 2006) is key to achieving this optimal condition. Gymnasts require a basic knowledge of nutrition. Establishing a suitable way of weight control for the elite gymnast, that includes physical condition balanced weight, injury prevention,enforcement of training program and performance, is an important aspect in competitive sport.

Table 3. *The body weight changes prior to intervention and following the intervention program*

	Prior to intervention			Following the intervention		
	June 13th 2008	June 28th 2008	Relative change in %	June 28th 2008	July 21st 2008	Relative change in %
Body weight (kg)	37.35	37.88	+1.4%	37.88	37.04	- 2.3 %
Body fat (g)	4065	4518	+10%	4518	4162	- 8.6 %

2. Help the athlete to understand the real meaning of body weight and body composition. Many methods have been used to measure body weight and body composition (McCardle, Katch, and Katch, 1994). Scales measure body weight only and provide no information regarding body composition. Body Mass Index provides information on body composition, but doesn't provide any information about body fat percentage (Houtkooper, Mullins, Going, Brown, & Lohman, 2001).

As discussed previously, weight of body fat is critically important to elite athlete's performance, particularly for gymnasts. GE Lunar Prodigy DF+301772 (from GE Healthcare) was used for giving the athlete a “true” indicator of body fat (Hetland, Haarbo, & Christiansen, 1998).

3. Combination of eating less and training more based on the results of this study the combination of “eating less” and “training more” can be effective in body weight control(Bogdanis, & Tsetsoni, 1999).

4. Does eating less or training more affect body weight effectively?

For a long time, elite athletes have expected for the answer about such questions seriously (Laquale, 2007). If above the competitive range and the athletes do more effort as they want to move faster, how can they get down closer to it? What is the best way to accomplish a lofty goal of dropping those last few pounds (Paul et al, 2006)? Unfortunately, studies on the best way for serious athletes to drop a few pounds are rare.

Based on our achievements the combination of “eat less” and “train more” perhaps can be much effective in the body weight control and better for athlete than only one choice. The optimal body weight for the training is very individually (Griffin, 1989). A functional program/system is required to answer this question and further study isneeded.

5. Food content faving reduced food intake prior to the Olympic Games, the content of food that is being eaten becomes more important(Rowlands, Thorp, Rossler, Graham, & Rockell, 2007). The food should provide enough energy for daily training and maintain an ideal body weight. Can protein bereduced? (Howarth, Moreau, Phillips, & Gibala, 2009). In this case, the athlete did not take milk and food that is rich in milk-protein as recommended, and she lost several grams of muscle, but it did not affect her performance.

6. When gymnasts eat less, what should be cut from their diet? A diet that is tailored to a training program is common for long term weight control, and keeping an energy-balanced diet (Gleeson, & Bishop, 2000) is key in this process. In this study the participant did not consume milk or other foods rich in milk-protein (Stroescu, Dragan, Simionescu, & Stroescu, 2001). Although the participant lost several grams of muscle, it did not influence her performance in competition. This brings about the question of how to reduce calorific intake and maintain muscle mass (Guest, 2005)? This is a difficult question to answer for athletes. Perhaps the bottom line is that when trying to lose those last few pounds of excess flab by cutting calories is more effective than increasing exercise volume and that a quality source of protein should be included in every meal.

7. Timing body weight lost in China, elite gymnasts spend most of their time in Beijing. There are four seasons in Beijing, winter is cold, summer is hot, spring and autumn are relatively dry. When an elite Gymnast needs to lose a few pounds we'd like to try to accomplish this in the early base period, because the mental and physical needs are not as intensive as in the process of preparing for competition. However, the challenge for most athletes is that time in the training season coincides with new year when a lot of food is typically consumed, this can prove a difficult time to lose weight. The best time in the season to lose weight is during the base period. The closer an athlete gets to the main competition the more detrimental calorie-cutting can be, as this this practice can be counterproductive in terms of recovery and performance. It is also difficult for the system provider to get about 10 to 12 weeks before the first competition in the year—then it's really too late and we need to accept whatever the athlete's body weight is and move on to the more challenging training.

CONCLUSION

In conclusion, the results of this study suggest that body weight control is an important aspect for elite gymnasts in preparation for competition. The regulation of food intake and energy balance contributes to the optimal body weight for performance.

Further studies are needed for body weight management of the top level gymnasts.

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

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Original research article

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.

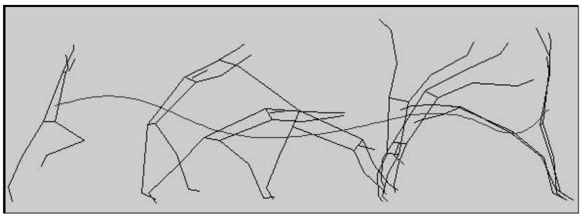
METHODS

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)



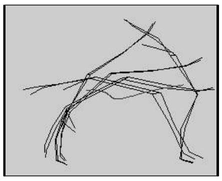
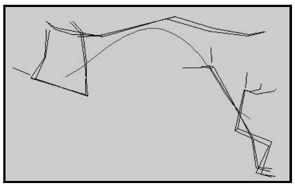
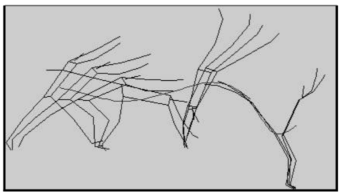
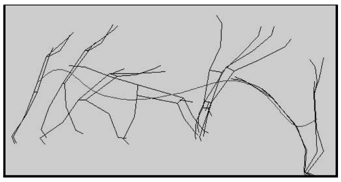
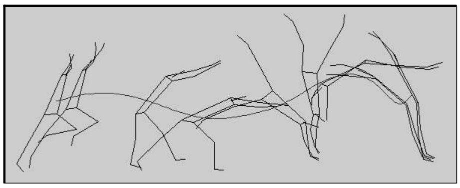
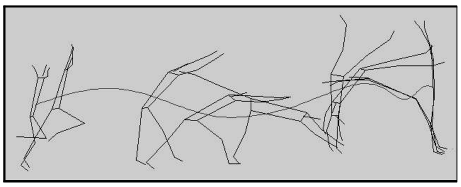
NAME OF THE TEACHING METHOD	**THE KINOGRAM OF THE TEACHING METHOD**
1 Drawing the co-gymnast over the back through the bridge (BRIDGE)	
2 Under swing dismount from parallel bars (UNSWIN)	
3 Forward handspring from the lunge and from a higher surface (FHLHS)	
4 Forward handspring from the hop and from 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

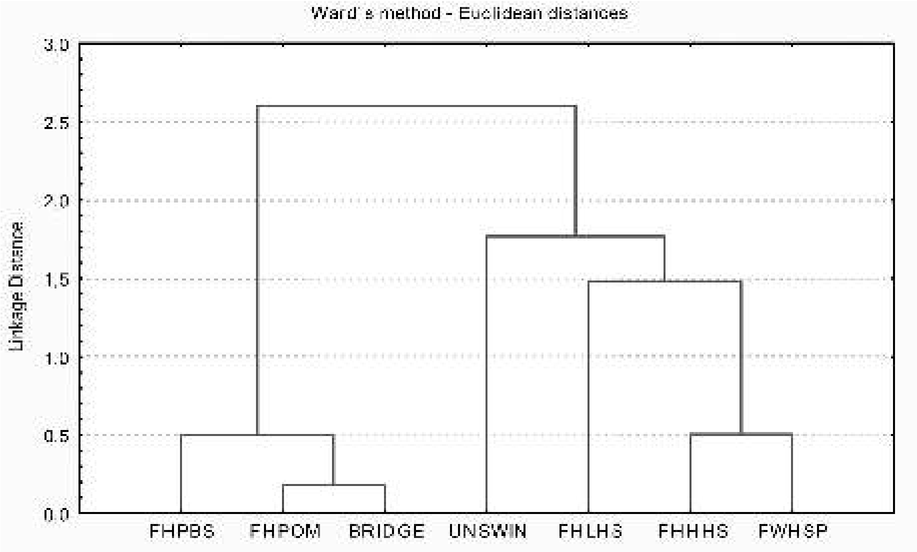


Figure 2. *Dendrogram of the hierarchical clustering of elements in the landing phase on the basis of spatial parameters*

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

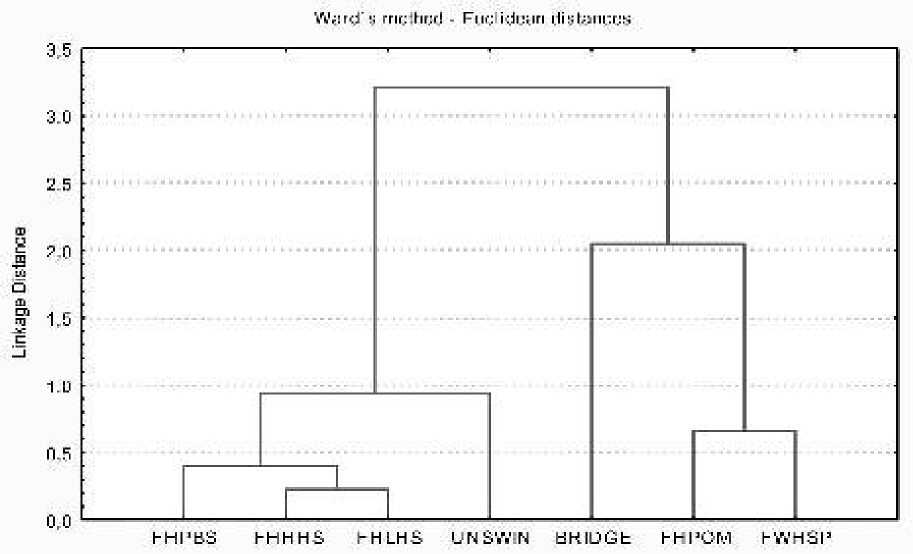


Figure 3. *Dendrogram of the hierarchical clustering of elements in the landing phase on the basis of time parameters*

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.

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LANDING CHARACTERISTICS IN MEN'S FLOOR EXERCISE ON EUROPEAN CHAMPIONSHIPS 2004

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Original research article

Abstract

In our research we focus on certain characteristics of salto landings that were performed on European Championships 2004. Our goal is to determine characteristics which have influence on the magnitude of the landing mistake. We analyzed saltos which were performed by senior gymnasts (N= 97) who were competing in the qualifications of the European Championships 2004 in Ljubljana. We defined the variables according to a theoretical model for the evaluation of salto landings in the floor exercise. The results show that axis of rotation, number of turns around longitudinal axis, and initial landing height have a significant impact on the magnitude of the landing mistake. The results also show that soft landing is most effective, landing after saltos without twists is optimal with feet together (unless gymnasts' abilities of left and right leg are different) and arms positions at touch down should be upward.

Key words: *Gymnastics, floor exercise, landings*

INTRODUCTION

Landing in modern gymnastics is one of the most important factors which determine the final rank of gymnasts in competitions. The goal of landing is to absorb the body's energy produced at take off. The gymnast has to asses the amount and direction of energy in the flight phase and anticipate the amount and direction of energy at landing. Direction of kinetic energy at contact can be oriented towards or away 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 then the total amount is equal to the sum of both energies. Therefore it is necessary for the stuck landing to develop such initial conditions that 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 acrobatic series. The ability of a gymnast to control a reaction force during the landing is limited by a muscular coordination, the ability of an individual to predict a magnitude of loading, and the ability to overcome a load, which is created at the time of contact with the surface (McNitt-Gray, Costa, Mathiyakom, and Requejo, 2001). If the body is not capable to efficiently control the loading at the time of landing, acute or overuse injuries can occur.

An additional problem is presented by the rule that the feet should be together at landings (FIG, 2006). One of important factor affecting stability is the magnitude of the base of support. The base of support is an area bound 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 gymnasts' stability. Another factor that affects stability is the angle between the line of action of a body's weight and 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.

Before making (un)necessary step(s) at landing, the gymnast can perform modification movements. Research have shown that the distribution of momentum among segments at 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 flight phase enables the gymnast to reach kinematics characteristics which are consistent with successful landings. After the contact, gymnasts can circle the arms in the same or the opposite direction to the direction of movement or lower his center of gravity. Modifications with hands help him to preserve and transfer angular momentum (Prassas & Gianikellis, 2002). When he lowers his center of gravity he enhances a time interval in which he can actively lower the impulse of the ground reaction force with his muscles.

Results from some studies show a rather low success of landings in competitions (McNitt-Gray, Requejo, Costa, & Mathiyakom, 2001; Prassas & Gianikellis, 2002). On Olympic games 1996 in Atlanta McNitt – Gray et. al. (1998) investigated landings from high bar and parallel bars. Competitors performed twenty landings. Only one was performed without a mistake.

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 linked with earlier phases. Therefore, it is important to know the types of landing mistakes in order to find the reasons for their occurrence.

In our research we will try to describe characteristics of saltos which were performed with landing mistakes and determine the influence of chosen variables on magnitude of error.

MATERIALS AND METHODS

In our research, we analyzed landings of saltos performed after an independent salto or at the end of an acrobatic series of saltos (N= 241). The analyzed saltos were performed by senior gymnasts (N= 97) who were competing in the of the European Championships 2004 in Ljubljana. For analysis we defined following variables:

1. Position of the body:
   - tucked
   - piked
   - stretched
2 Initial landing height (at contact):
   - high landing (body's center of gravity is above the hips)
   - medium landing (body's center of gravity is in the height of the hips)
   - low landing (body's center of gravity is below the hips)
3. Axis of rotation (in accordance with FIG's Code of Points 2006):
   - around transverse axis (saltos forward and saltos backward)
   - around sagital axis (saltos sideways)
   - complex rotations
     - forward around transverse and around longitudinal axis (saltos forward with turns)
     - backward around transverse and around longitudinal axis (saltos backward with turns)
     - around longitudinal and forward or backward around transversal (jumps with ½ turn to saltos forward or backward)
4. Number of turns around transverse axis (90^0 of salto = 1)
5. Number of turns around longitudinal axis (180^0 of salto = 1)
6. Number of turns around sagital axis (90^0 of salto = 1)
7. Base of support:
   - feet together
   - <=shoulder width
   - >=shoulder width
   - support with hands
8. Amortization
   - stiff landing
   - soft landing
   - deep landing
9. Hands position at contact:

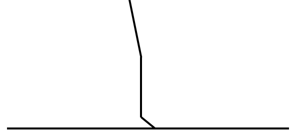

Figure 1: *forward position*

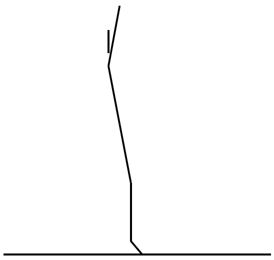

Figure 2: *upward position*

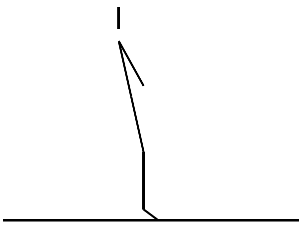

Figure 3: *downward position*

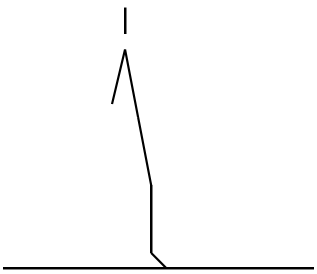

Figure 4: *backward position*

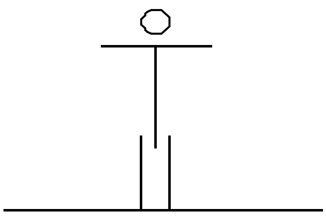

Figure 5: *outward position*

Landings were determined with video analyses (50Hz). For all variables we computed the frequencies and their percentages in comparison with the magnitude of the landing mistake (cross tabs). With Chi square test we determined the difference between good landings and bad landings by virtue of the differences between these landings as operationalized by the selected variables.

RESULTS

Out of all performed saltos with the intention to stick the landing at the EC 2004 (N = 344), 30 % (N = 103) were performed without error and 70 % (N = 241) were performed with errors. Distribution of the error magnitudes among saltos with errors (N = 241) is: small errors (62,7 %), medium errors (31,5 %), large errors (1,7 %) and falls (4,1 %) (Table 1). Short hop (37,3 %), short step (25,3 %) and large step (23,2 %) are the most frequent mistakes made. Large errors were always made by falling to support with both hands on the floor. The highest frequency of small errors was in the high and medium initial landing height, while most medium and large errors and all falls were performed with a low initial landing height and these differences between the magnitude of error and the initial landing height are statistically significant
(Table 2).

The most frequent landing errors occurred during saltos forward (fwd.) with and without turns (51,0 %; N = 123), much less so saltos backward (bwd.) with or without turns (34,9 %; N = 84), and the lowest frequency saltos with ½ turn and salto or saltos sideways (14,1 %; N = 34). Forward saltos with turns (29,0 %) were performed more frequently with. errors than saltos fwd. without turns (22,0 %). Saltos bwd. with turns (27,0 %) were also performed more frequently with errors than saltos bwd. without turns (7,9 %). Gymnasts did 12,0 % saltos with ½ turn and salto with errors while only 2,1 % of saltos sideways were performed with errors (Table 3). The differences between the magnitude of error and the axis of rotation are statistically significant.

The highest frequency of small errors occurred with saltos bwd. with turns (28,5 %; N = 43) and saltos fwd. with turns (26,5 %. N = 40), followed by saltos fwd. (19,2 %; N = 29), saltos with ½ turn to saltos fwd. or bwd. (15,2 %;

Table 1: *Distribution of saltos with landing mistakes according to the magnitude and the type of the landing mistake*

	Number of saltos	% according to magnitude of error	% according to type of error
Small error	151	62.7 %	
- short step	61		25.3 %
- short hop	90		37.3 %
Medium error	76	31.5 %	
- large step	56		23.2 %
- large hop	20		8.3 %
Large error	4	1.7 %	
- touch with hands	0		0.0 %
- support with hands	4		1.7 %
Fall	10	4.1 %	
Sum	**241**		

Table 2: *Distribution of the magnitude of errors and the initial landing height*

	Magnitude of error							Sum
INITIAL LANDING HEIGHT	Small		Medium		Large		Fall	
	Step	Hop	Step	Hop	Touch	Support		
High landing	**22**	**26**	**13**	**12**		**1**		**69**
% within initial landing height	31.9 %	37.7 %	18.8 %	17.4 %		1.4 %		100.0 %
% within magnitude of error	36.1 %	28.9 %	23.2 %	60.0 %		25.0 %		28.6%
Medium landing	**20**	**40**	**22**	**3**		**1**		**78**
% within initial landing height	25.6 %	51.3 %	28.2 %	3.8 %		1.3 %		100.0 %
% within magnitude of error	32.8 %	44.4 %	39.3 %	15.0 %		25.0 %		32.4 %
Low landing	**19**	**24**	**21**	**5**		**2**	**10**	**70**
% within initial landing height	27.1 %	34.3 %	30.0 %	7.1 %		2.9 %	14.3 %	100.0 %
% within magnitude of error	31.1 %	26.7 %	37.5 %	25.0 %		50.0 %	100.0 %	29.0 %
Sum	**61**	**90**	**56**	**20**	**0**	**4**	**10**	**241**
% within initial landing height	25.3 %	37.3 %	23.2 %	8.3 %	0.0 %	1.7 %	4.1 %	100.0 %

Chi square test between magnitude of error and initial landing height		
Value	Degrees of freedom	Significance
20.323	6	0.002

N = 23) and saltos bwd. (7,3 %; N = 11); the lowest frequency of errors occurred in saltos sideways (3,3 %; N = 5). Small errors show that gymnasts did more often a small hop rather than a small step. A small hop was more often seen in saltos fwd. with turns, while a small step was more foften observed in saltos bwd. with turns. Medium errors mostly occurred in saltos fwd. with turns (35,5 %; N = 27) and without turns (35,5 %; N = 27); slightly less frequently in saltos bwd. with turns (23,7 %; N = 18) and in saltos bwd. without turns (10,5 %; N=8); only only 7,9 % of saltos with ½ turn to saltos fwd. or bwd. were performed with medium errors (N=6). In middle errors, there is higher prevalence of long steps than long hops. All large errors occurred in saltos backward and all falls happened in saltos forward (Table 3).

Table 3: *Distribution of landing mistakes according to the axis of rotation*

	Magnitude of error							Sum
AXIS OF ROTATION	Small		Medium		Large		Fall	
	Step	Hop	Step	Hop	Touch	Support		
Salto fwd.	**14**	**15**	**14**	**13**			**7**	**53**
% within axis of rotation	26.4 %	28.3 %	26.4 %	24.5 %			13.2 %	100.0 %
% within magnitude of error	23.0 %	16.7 %	25.0 %	65.0 %			70.0 %	22.0 %
Salto fwd.with turns	**13**	**27**	**21**	**6**			**3**	**70**
% within axis of rotation	18.6 %	38.6 %	30.0 %	8.6 %			4.3 %	100.0 %
% within magnitude of error	21.3 %	30.0%	37.5%	30.0%			30.0%	29.0 %
Salto bwd.	**2**	**9**	**7**	**1**				**19**
% within axis of rotation	10.5 %	47.4 %	36.8 %	5.3 %				100.0 %
% within magnitude of error	3.3 %	10.0 %	12.5 %	5.0 %				7.9 %
Salto bwd. with turns	**18**	**25**	**10**	**8**		**4**		**65**
% within axis of rotation	27.7 %	38.5 %	15.4 %	12.3 %		6.2 %		100.0 %
% within magnitude of error	29.5 %	27.8 %	17.9 %	40.0 %		100.0 %		27.0 %
Saltos sideways	**3**	**2**						**5**
% within axis of rotation	60.0 %	40.0 %						100.0 %
% within magnitude of error	4.9 %	2.2 %						2.1 %
Jumps with ½ turn to saltos fwd. or bwd.	**11**	**12**	**4**	**2**				**29**
% within axis of rotation	37.9 %	41.4 %	13.8 %	6.9 %				100.0 %
% within magnitude of error	18.0 %	13.3 %	7.1 %	10.0 %				12.0 %
Sum	**61**	**90**	**56**	**20**		**4**	**10**	**241**
% within axis of rotation	25.3 %	37.3 %	23.2 %	8.3 %	0.0 %	1.7 %	4.1 %	100.0 %

Chi square test between landing mistakes and axis of rotation		
Value	Degrees of freedom	Significance
34.415	15	0.003

The highest frequency of errors was noticed in saltos with turns (68,5 %). The difference between the number of turns and the magnitude of error is significant. Small errors and falls are most frequent in saltos without turns, while middle and large errors are mostly performed in saltos with turns. Small hops are characteristic of small errors and large steps are a more frequent medium error (Table 4).

Base of support at landing and magnitude of error showed statistically significant differences (Table 6). A bigger base of support should mean a larger error deduction (also according to Code of Points (FIG, 2006). Most of the landings are to a standing position with legs apart up to hip width (69,6 %), fewer landings led to a stand with feet together (17,1 %) and to stand with feet apart more than hip width (11,5 %) and the smallest number of landings were to a support on the arms (1,8 %).
Between magnitude of error and type of amortization there are statistically significant differences (Table 6). The numerous errors were observed during soft landings (58,9 %), followed by stiff landings (37,3 %) and deep landings (3,7 %). Large errors and falls mostly occured with deep landings (11,1 % and 22,2 %) and stiff landings (2,2 % and 5,6 %), and less on soft landings (0,7 % and 2,1 %).

Between the magnitudes of errors and hand positions at contact there were statistically significant differences (Table 7). Gymnasts have had mostly arms in outward position (53,1 %), than forward position (18,4 %), downward position (17,0 %), upward position (9,8 %) and backward position (1,2 %). The highest number of small (55,6 %) and medium (56,6 %) errors occurred with outward arms position. The highest number of large errors (50,0 %) occurred with forward arms position and the largest amount of falls occurred with arms in downward position.

Differences between body positions during the flight, the number of turns around the transverse axis and the number of turns around the sagital axis were not statistically significant (Table 8).

Table 4: *Distribution of landing mistakes according to the number of turns around the longitudinal axis*

	Magnitude errors							Sum
NUM. OF TURNS – LONGIT. AXIS	Small		Medium		Large		Fall	
	Step	Hop	Step	Hop	Touch	Support		
Without twist	**18**	**26**	**21**	**4**			**7**	**76**
% within number of turns	23.7 %	34.2 %	27.6 %	5.3 %			9.2 %	
% within magnitude of error	29.5 %	28.9 %	37.5 %	20.0 %			70.0 %	31.5 %
1/2 (180^0)	**11**	**14**	**5**	**3**				**33**
% within number of turns	33.3 %	42.4 %	15.2 %	9.1 %				
% within magnitude of error	18.0 %	15.6 %	8.9 %	15.0 %				13.7 %
1/1 (360^0)	**12**	**16**	**15**	**2**			**1**	**46**
% within number of turns	26.1 %	34.8 %	32.6 %	4.3 %			2.2 %	
% within magnitude of error	19.7 %	17.8 %	26.8 %	10.0 %			10.0 %	19.1 %
3/2 (540^0)	**7**	**16**	**6**	**4**			**2**	**35**
% within number of turns	20.0 %	45.7 %	17.1 %	11.4 %			5.7 %	
% within magnitude of error	11.5 %	17.8 %	10.7 %	20.0 %			20.0 %	14.5 %
2/1 (720^0)	**12**	**18**	**6**	**7**		**3**		**46**
% within number of turns	26.1 %	39.1 %	13.0 %	15.2 %		6.5 %		
% within magnitude of error	19.7 %	20.0 %	10.7 %	35.0 %		75.0 %		19.1 %
5/2 (900^0)	**1**		**3**			**1**		**5**
% within number of turns	20.0 %		60.0 %			20.0 %		
% within magnitude of error	1.6 %		5.4 %			25.0 %		2.1 %
sum	**61**	**90**	**56**	**20**		**4**	**10**	**241**
% within number of turns	25.3 %	37.3 %	23.2 %	8.3 %	0.0 %	1.7 %	4.1 %	100.0 %

Chi square test between magnitude errors and number of turns around longitudinal axis		
Value	Degrees of freedom	Significance
33.978	15	0.003

Table 5: *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

CONCLUSSION

Each element is expected to be performed to the perfect end position (FIG, 2006). Any deviation from the perfect end position means error and is penalized by the judges. Errors on landings are caused by the previous phases of the element, e.g., the take off and the flight. Flight characteristics, such as the

Table 6: *Distribution of the magnitude of error and the 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 7: *Distribution of the magnitude of error and the hands position at contacts*

	Magnitude of error							sum
HANDS POSITION AT CONTACT	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

axis of rotation, the number of turns or the initial landing height, appear to influence the success and quality of landing.

The salto's height is important for the initial landing height. The lower the initial landing height the higher the probability of a larger error. With a lower initial landing height the time for landing preparation is shorter which means a higher probability for an error. With a higher initial landing height, the time for landing preparation is longer and therefore there is less room for errors. It is very important to perform saltos with high amplitude and prolonged flight time for landing preparation.

The gymnast needs to solve different tasks during his training – landing from different heights (saltos from horse, springboard, mini trampoline etc.) (Minetti, Ardigo, Susta, & Cotelli, 1998) and landing saltos with different angular velocities (»fast« salto, »slow« salto)

Table 8: *Chi square test between magnitude of error and other variables*

Chi square test between magnitude of error and:			
	Value	Degrees of freedom	Significance
Body position	5.534	6	0.477
Number of turns around transverse axis	11.896	9	0.219
Number of turns around sagital axis	3.043	3	0.385

and to do landings on different surfaces (soft, hard, elastic, etc.). Athlete's training should change so that the athlete is better able to correct positions in the air and upon contact with the surface. The gymnast will acquire the knowledge to adjust his landing according to the circumstances and therefore become more successful.

Coaches should be more focused on correct landings during saltos with turns as the load on the left and on the right legs are different. Also, coaches should be more focused on the take off characteristics, aiming to prolong the time of flight during saltos with turns as height gives better chances of stuck landings. For more turns during saltos, higher angular velocity around the longitudinal axis is needed, which makes stuck landings more difficult to achieve or control. The gymnast receives during saltos with turns at least two types of backup information: the first type is about the technical execution of elements (e.g. how many turns have already been performed) and the second is about the landing execution (what corrections are needed for the perfect landing). During element execution, both information types are coming into the central nervous system and they require different reactions. In our opinion, problems occur when an element has not yet been mastered and the gymnast is focused on its technical execution information which disables the processing and the use of information for the landing execution. Usually such processing problems end with an uncontrolled landing and a large error or fall. Among other things, the gymnast also receives information from the environment (e.g. cheering, applauding, music, bright light etc.) and a correct selection of this information is also needed. During his training, the gymnast needs to learn to select the useful information which will lead him to the stuck landing.with the surface. The gymnast will acquire the knowledge to adjust his landing according to the stuck landing.

Stuck landings were performed with different foot positions. Mostly they perform the landing with legs apart up to hip width, but this type of landing was not very successful. Stability of body in forward and backward direction (saltos without twists) is not better if feet are apart as stability angle does not rise as well, so to land with legs apart has no biomechanics reason. Such landing with feet apart (raised base of support) are successful with landing after sideways salto and with saltos with twists as stability angle in left right direction is raised.

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

Before gymnasts perform unnecessary hops or steps during the landing, they can also do some other movements to correct position such as – swing with arms in or opposite the direction of movement. The smallest errors were observed while the gymnast held their arms in an upward position at the moment of touch down with the feet. The highest amount of errors we noticed with an arms downward position. The arms upward position is the best as the arms can swing forward, backward, outward in accordance with landing characteristics.

Only 30 % of saltos we analyzed were performed to a stuck landing. This means that a huge majority of coaches and gymnasts should restructure their training programs by type of activity and by loads in order to raise the skill level of their landings.

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THE DISCOURSE OF THE EPISTEMIC COMMUNITY OF ARTISTIC GYMNASTICS: THE ANALYSIS OF ARTICLES' TITLES

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Original research article

Abstract

The goal of this study was to analyse 105 titles of articles published in 43 journals that are indexed in at least one of the three databases - ScienceDirect, MEDLINE and Scopus - in order to describe the epistemic community that deals with gymnastics-related topics. To analyse the collected data frequencies, Pearson Chi-square test and the hierarchical cluster analysis were used. The results showed that most articles were written by two or three authors, and that the titles written by two, three and four authors contained the largest number of words of Latin etymology. Words of Latin origin were used significantly more frequently than those of the English origin, whereas a word of Greek origin was used almost as frequently as a word of English origin. The word class most frequently used in the titles was the nouns. Neither the number of words of Latin origin per title nor the number of words of Greek origin differed significantly by the publication year. The cluster analysis showed that the principal cluster was formed of lexical words which were nouns predominantly of Latin origin. The results of this research showed that the scientific discourse of the analysed titles concurs with the basic principles of academic writing and that the epistemic community of artistic gymnastics can be identified by its specific vocabulary.

Key words: *titles, etymology, scientific discourse, academic writing*

INTRODUCTION

Epistemology shows that kinesiology employs different but complementary methods for gaining knowledge (Estes, 1994). The body of knowledge in kinesiology is said to be derived from various other disciplines. Already more than 70 years ago Sharman (1934, cited in Estes, 1994) said that “the subject matter of [physical and health education]” – considered to be the foundation stone from which the concept of kinesiology has emerged (e.g. Wrynn, 2003) – “is made up largely of material taken from biology, sociology, and education”. His contemporaries Nixon and Cozens (1941, 42-43, cited in Estes, 1994) stated in a similar way that “the scientific foundations of modern physical education are to be discovered in the main in sociology, psychology, and the various branches of biology”. Contemporary standpoint is that the subdisciplines comprising the contents of kinesiology are sport pedagogy, exercise physiology, sport biomechanics, sport humanities (sport history, sport philosophy, and sport literature), sport psychology, sport sociology, measurement and evaluation, and finally, motor development (Estes, 1994). In other words, the concepts usually studied in kinesiology belong to the areas of human anatomy, physical growth, motor development, biomechanical aspects of movement, acute and chronic effects of exercise, behavioural and neuromuscular control of movement, acquisition of motor skills, psychological factors in movement, exercise, sport, sociocultural factors in movement, and history/philosophy of movement (Charles, 1994).

Language symbolically represents information (Love, 2009). The common attitude says that words comprise the mental lexicon (Elman, 2004). However, there are various types of discourse that use language as a means of transferring information – political discourse, scientific discourse, etc.

The discourse of science is known to be well-structured. Bernstein (2000, p. 157, cited in Moore and Muller, 2002) distinguishes between two types of discourse – horizontal discourse, i.e. the 'everyday' discourse, and the vertical discourse which has a coherent, explicit and systematically principled structure that is either hierarchically organized as in the sciences (hierarchical knowledge structure), or takes the form of a series of specialized languages as in the social sciences and humanities (horizontal knowledge structure) (Moore & Muller, 2002). Further, each scientific discipline has its own terminology. According to Eugene Wüster (Felber, 1980), founder of the general theory of terminology, to improve the communication between experts in certain field, it is necessary to develop an appropriate instrument and that instrument is terminology which is considered to be one of the basic epistemological components of each science. As an epistemological characteristic, terminology is inherent to methodology, among other things because it strives towards a higher level of notional generalization, and each higher level demands more clear notions (Milat, 2005, p. 35). Neither scientific division nor scientific classification is possible without accurate terminology (Milat, 2005, p. 35). Milat (2005, p. 35) continues and says that accurate terminology is a prerequisite of valid scientific communication.

Like all other sciences, kinesiology also has its terminology. In accordance with the sciences considered to comprise the contents of kinesiology, its terminology is a conglomerate of terminologies from scientific disciplines such as physiology, sociology, anthropology on the one hand, and terminologies pertaining to sport and physical exercise on the other hand. Still, as in all other sciences, there are terminological problems in kinesiology that must be carefully dealt with (Starosta and Petrinsky, 2007) in order to make this terminology unambiguous.

Human anatomy is a science that contains more terms originating from Latin and Greek than any other scientific discipline. According to *Dorland's Illustrated Medical Dictionary* (1994, xxi), in anatomy, surgery as well as in clinical and laboratory medicine, Greek and Graeco-Latin terms have always comprised more than 90% of technical terms used. Since gymnastics is based on human anatomy, physiology of sport and exercise, biomechanical laws and biochemical principles which all belong to the domain of exact sciences, anatomy and physiology as branches of biology, biochemistry as a branch of chemistry, and biomechanics, as a branch of mechanics, i.e. a branch of physics, it will be interesting to analyse the language used in the titles of scientific texts on topics from its domain.

The analysis in this study is based on the assumption regarding the existence of epistemic communities. As Roth and Bourgine (2005) say, Haas (1992) introduced the notion of epistemic community and defined it as "a network of knowledge-based experts (...) with an authoritative claim to policy-relevant knowledge within the domain of their expertise". Roth and Bourgine (2005) further describe that this definition was supplemented by Cowan, David and Foray (2000) who said that an epistemic community must share a subset of concepts. The research collaborators must explicitly state their particular discipline's knowledge structure which is defined in five categories: disciplinary history and forms of scientific knowledge, spatial and temporal scales of that knowledge, precision (i.e. quantitative and qualitative forms), accuracy of predictions, and availability of data to construct, calibrate, and test predictive models (Boulton, Panizzon, and Prior, 2005). Therefore, epistemic community can be defined in various ways; however, they all concur that it is a group of agents who share and work within the same epistemic framework and towards a certain knowledge-related goal, on a given subset of concepts (Roth and Bourgine, 2005). The subset of concepts is in the analysis in this paper represented by words since, as Roth and Bourgine (2005) say, concepts can be got from words and nominal groups (terms).

Hence, similarly to Roth and Bourgine's analysis in which the sample was drawn from the population of titles, full texts and key words, our sample were the titles of articles published in various journals. However, the data were treated according to methodology different from the one applied by Roth and Bourgine in their research (2005). The purpose of their paper was to determine the existence of epistemic communities on the basis of words. In our study we used words as concepts to describe the discourse of the epistemic community of artistic gymnastics.

The goal of this analysis was to analyse 105 titles of articles published in 43 journals that are indexed in at least one of the following three databases: ScienceDirect, MEDLINE and Scopus, in order to describe the epistemic community that deals with artistic gymnastics-related topics.

METHODS

Data collection

ScienceDirect, a full-text scientific database, covers a wide range of the world's STM (Science, Technical and Medical) articles. The titles from this database were collected in the following way. First, the time period for the search was restricted to the years between 1999 and 2009 and the option *All sources* was limited to *Journals*. The key words *artistic* AND *gymnastics*, *balance beam* AND *gymnastics*, *vault* AND *gymnastics*, *asymmetric/uneven bars* AND *gymnastics*, *parallel bars* AND *gymnastics*, *horizontal bar/high bar* AND *gymnastics*, *pommel horse* AND *gymnastics*, *rings* AND *gymnastics* and *floor* AND *gymnastics* were then used for the search within the *Abstract, Title, Keywords* option. Altogether 30 titles were found that addressed the topic of artistic gymnastics. However, due to the polysemy, i.e. the diversity of meanings of the word *ring*, which resulted in finding the titles dealing with physics and medicine – in the latter, the research focused on the ring muscle (sphincter) gymnastics for spinal cord injured – meaning that the notion of the term *gymnastics* did not relate to artistic gymnastics, three titles/articles were omitted from further analysis.

MEDLINE, a bibliographic database, contains references of journal articles in life sciences with a concentration on biomedicine. To search this database the time period was again limited to the years from 1999 to 2009 and only the words *artistic* and *gymnastics* were written into the *Basic search* option. The search done by using the key words *artistic* and *gymnastics* alone yielded the total of 1,126 articles/titles covering a rather broad range of various meanings of the word *gymnastics*. Such a large number of titles was the result of the fact that first the titles and abstracts of articles that contain both the word *artistic* and the word *gymnastics* were listed followed by the titles containing either of the two words. Other key words used to search the database ScienceDirect were not used here since the already obtained selection was quite comprehensive. The initial number of 1,126 articles was far too large for the purposes of this article and therefore 113 articles with focus on the concept covered by the term *gymnastics* were chosen at random. Next, the titles already found in the database ScienceDirect were omitted from further analysis as well as the titles that obviously addressed a much broader range of the term *gymnastics* than covered by the term *artistic gymnastics*. Additionally, one title relating exclusively to rhythmic gymnastics was also omitted. A total of 68 articles remained.

Scopus is a bibliographic database with abstracts and citations, which covers literature and web resources in the field of social sciences, but also has strength in life, health and physical sciences. To search this database, again only the words *artistic* and *gymnastics* were used and 19 articles, i.e. their titles, published between the year 1999 and 2009 were found. Since 9 titles have already been selected from the previous two databases and considered for research, the number of titles that remained in further research was 10.

Hence, the ultimate number of cases, i.e. the titles of articles in the sample was 105. These 105 articles were published in 43 different journals.

The categorization of words from the titles as regards their etymology was done as follows.

There were cases of terms consisting of two or more morphemes originating from the same language, e.g. *amenorrhea* that was coined from the Greek prefix *a-* and two combining forms – *meno-* and *–rrhea* – both of Greek origin. Another example is the term *uneven* that was created from the base, *even*, that is of Old English origin - *efen* (*Random House Webster's Unabridged Dictionary*, 1999), and the prefix *un-* that is also of Old English origin. The same applies to the noun *menarche* that consists of *meno-*, a combining form borrowed from Greek, and *arch£* also from Greek. In such cases there was no doubt as regards the origin of the word/term.

In cases when the morphemes that comprised the term originated from different languages the following principle was applied. For example, the word *preflight* was categorized as being of English origin – the base *flight* originates from Old English, however, the prefix *pre-* is of Latin etymology. Hence, it was the base of the word that was used as a criterion for its categorization.

Variables

The variables used in this analysis were – *publication year (the year in which an article was published)*, *number of authors* (the number of authors of an article), *lexical word* (number of lexical words per title), *verbs* (number of verbs per title), *nouns* (number of nouns per title), *adjectives* (number of adjectives per title), *Latin* (number of words/terms of Latin etymology per title), *Greek* (number of words/terms of Greek etymology per title), *English* (number of words/terms of English etymology per title), *French* (number of words/terms of French etymology per title), *Old Norse* (number of words/terms of Old Norse etymology per title) and *Other* (number of words/terms of etymology in other languages per title). As for the last variable – *Other* – there were not many words/terms that originated from languages other than Latin, English, Greek, French or Old Norse. Two will be mentioned here for illustration. The word *average*, i.e. its earlier form *averay* meant *charge on goods shipped*, i.e. originally it meant *duty* (*Random House Webster's Unabridged Dictionary*, 1999). The word entered English from Middle French (*avarie*) into which itcame from Old Italian (*avaria*), and the language of origin is Arabic (*'aw!r#yah* meaning *damaged merchandise*) (*Random House Webster's Unabridged Dictionary*, 1999). The term *felge* is a loan-word from German (*Felge*).

Statistical analyses

To analyse the collected data frequencies, Pearson Chi-square test and hierarchical cluster analysis were used. The significance level considered was $p \leq .05$. The Chi-square test was used to identify the differences between the *number of authors*, between the *number of words/terms of Latin etymology per title* and between the *number of words/terms of Greek etymology per title* as regards the *publication year* on the one hand, and on the other to identify the differences between the *number of words/terms of Latin etymology per title* and between the *number of words/terms of Greek etymology per title* as regards the *number of authors*. The number of words from French, English, Old Norse and other languages was not taken into account in the Chi-square test since the number of words/terms originating from Latin and Greek were in the focus. Finally, to perform the hierarchical cluster analysis (tree clustering method), the data were first standardized and the 12 variables were then submitted to the analysis to find out whether they formed any meaningful structures. The statistical package *Statistica 7.0 for Windows* was used to process the data.

RESULTS

The largest number of articles – 15, i.e. 14.3%, and 10, i.e. 9.5% – was found in two journals whose domain is biomechanics. In other words, considered by journal domain, the largest number of topics was devoted to biomechanics. The third largest number of articles (9, i.e. 8.6%) was found in the journal whose domain is broader than the twopreviously mentioned, and in which the topics-dealt with were, for example, sport- and psychology-related issues, juries' evaluation processes, judging/scoring, auditory feedback and self- and expert-modelling. Between 1 and 6 articles dealing with gymnastics-related issues were found in other journals.

The number of articles published increased after 2004 (1999 – 5; 2000 – 9; 2001 – 3; 2002 – 7; 2003 – 13; 2004 – 5; 2005 – 12; 2006 – 12; 2007 – 15; 2008 – 17; 2009 – 7 articles thus far).

Table 1 shows that the number of authors ranged from one to seven, however, that most articles were written by two or three authors, followed by the number of articles written by more than three authors. What is interesting is that only ten articles were written by only one author.

As for the relationship between the *publication year* and the *number of authors*, the Pearson Chi-square test showed significant differences ($\chi2=93.44$; $df=60$; $p=.004$). The articles written by only one author appeared around the years 2000, 2004, 2007 and 2008. Except for the year 2007, the other three years mentioned were Olympic years.

Starting from 2003 the titles contained slightly more words of Latin origin than previously, whereas such difference was not to be noticed when the usage of words of Greek origin is concerned. Still, neither the number of words of Latin origin nor the number of words of Greek origin used in the titles differed significantly by the publication year.

Altogether 889 lexical words were used in the titles and 397 function words, i.e. less than a half of lexical words (Figure 1). Considering the 889 lexical words in 105 titles analysed, a word of Latin etymology occurred 460 times (51.7%) and a word of Greek origin 177 times (19.9%). In other words, 71.6% of all lexical words used in 105 titles were either of Latin or Greek etymology. The average number of lexical words in the titles was 8.47.

173 times a word of English etymology was used in the titles, 45 times a word of French origin (for example, *jury*, *judgement*, etc.), 11 times a word originating from Old Norse, the Germanic language spoken in medieval Scandinavia – for example, *skill*, *skin*, *score*, etc. – and 18 times a word whose etymology is to be traced to other languages, for example, Old Danish (*link*), *average* from Arabic, *Felge* from German, etc. Also the terms denoting artistic gymnastics elements were found that were named after the gymnasts who invented them, e.g. Azarian, Yurchenko and Tkatchev.

In other words, a word of Latin etymology was used more than two times more frequently than a word of English origin (Figure 2) and a word of Greek origin was used almost as frequently as a word of English origin. The average number of words of Latin origin was 4.38.

As for lexical words, the word class most frequently used in the titles was the nouns (623), followed by adjectives (219) and verbs (42) (Figure 3). The remaining five words were adverbs.

Significant differences were found (χ^2=90.42; df=66; p=.02) in the *number of words/terms of Latin etymology per title* used in the titles as regards the *number of authors*, however, not in the *number of words/terms of Greek etymology per title*. The titles written by two, three and four authors contained the largest number of words of Latin etymology.

The Euclidean distances (Table 2) and the hierarchical tree plot (Figure 4) show that the tree clustering plot developed in the following way. The principal cluster was formed of lexical words and nouns. In the next node *Latin etymology* joined the cluster, followed by *adjectives*, and *English* and *Greek etymology*. Next, the *number of authors* was added to the cluster. In other words, most lexical words in the 105 analysed titles were nouns that were predominantly of Latin origin. The cluster further developed by adjoining the following most frequent word class of lexical words – *adjectives* – and the etymology of lexical words expanded to *English* and *Greek*.

Table 1. *Frequency and percentage of articles by the number of authors*

NUMBER OF AUTHORS	FREQUENCY	PERCENT
One	10	9.5
Two	27	25.7
Three	28	26.7
Four	13	12.4
Five	14	13.3
Six	11	10.5
Seven	2	1.9

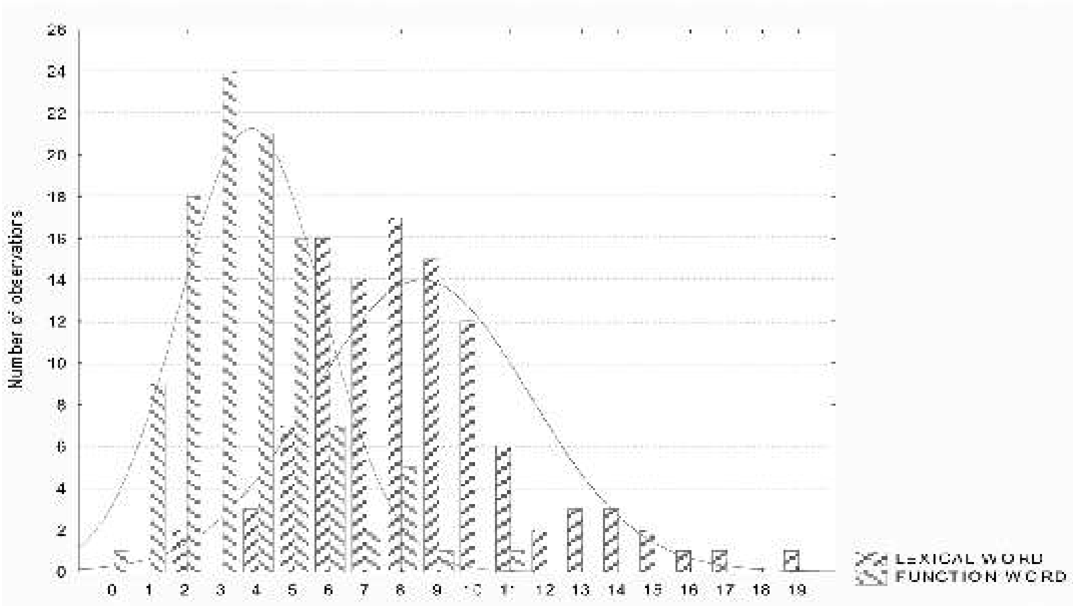

Figure 1. *Frequency distributions of lexical and function words used in the titles (Legend: LEXICAL WORD – number of lexical words per title; FUNCTION - number of function words per title)*

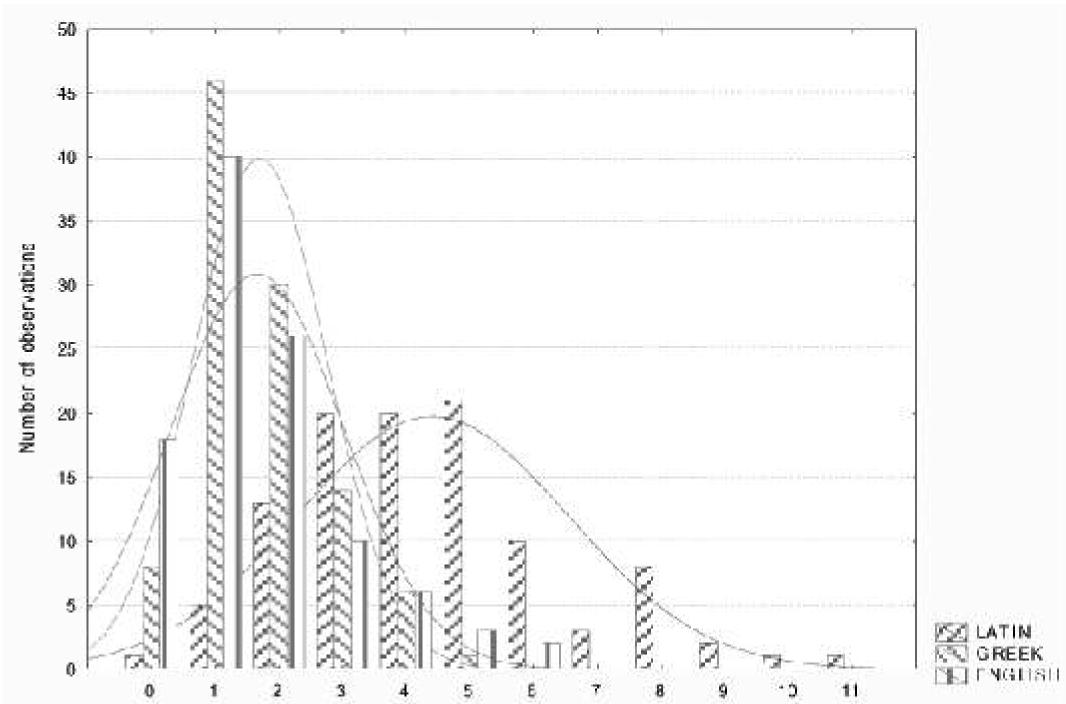

Figure 2. *Frequency distributions of words of Latin, Greek and English etymology used in the titles (Legend: LATIN - number of words/terms of Latin etymology per title; GREEK - number of words/terms of Greek etymology per title; ENGLISH - number of words/terms of English etymology per title)*

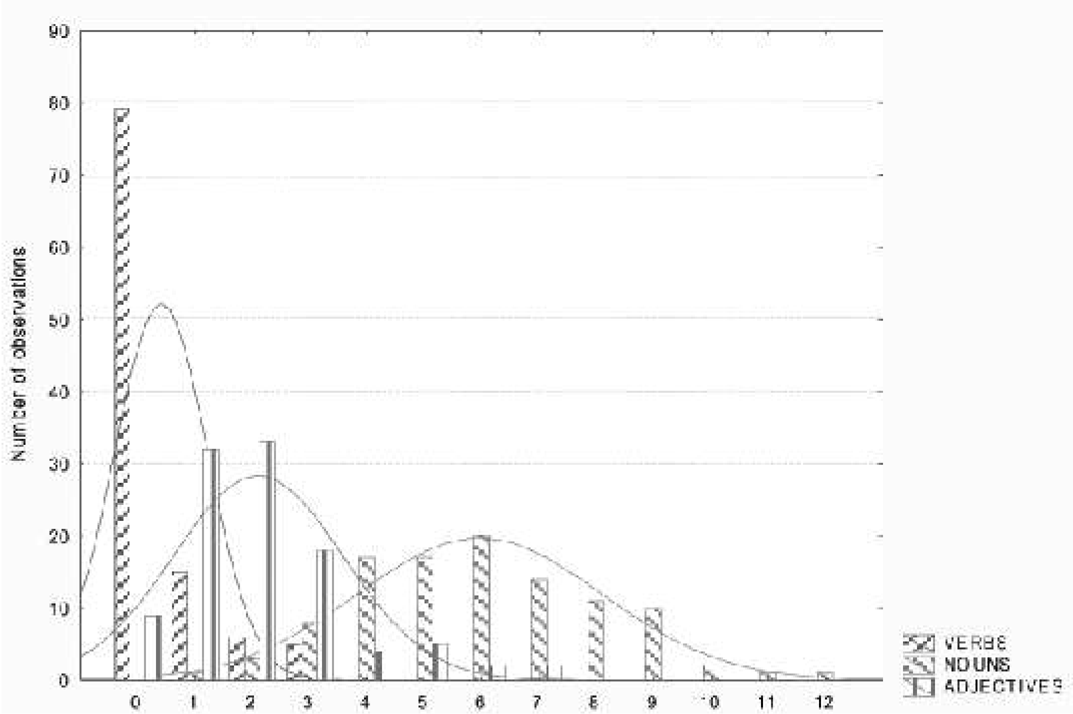

Figure 3. *Frequency distributions of three word classes – nouns, adjectives and verbs – in the titles (Legend: VERBS - number of verbs per title; NOUNS - number of nouns per title; ADJECTIVES - number of adjectives per title)*

Table 2. *Table of Euclidean distances*

VARIABLE	*PUBLICATION YEAR*	*NUMBER OF AUTHORS*	*LEXICAL WORD*	*VERBS*	*NOUNS*	*ADJECTIVES*	*LATIN*	*GREEK*	*FRENCH*	*OLD NORSE*	*ENGLISH*	**OTHER**
PUBLICATION YEAR	.0	14.9	13.6	13.2	14.0	14.2	13.1	15.3	13.2	15.6	14.5	13.6
NO. OF AUTHORS	14.9	.0	12.2	14.3	11.8	14.0	12.2	13.9	15.0	14.2	12.8	15.3
LEXICAL WORD	13.6	12.2	.0	12.8	6.5	8.1	6.8	11.4	13.2	13.2	10.6	13.9
VERBS	13.2	14.3	12.8	.0	14.9	14.3	13.2	14.4	14.4	14.0	14.4	13.1
NOUNS	14.0	11.8	6.5	14.9	.0	12.6	8.0	13.0	14.0	12.6	11.0	13.4
ADJECTIVES	14.2	14.0	8.1	14.3	12.6	.0	10.4	10.8	12.8	14.6	12.3	15.8
LATIN	13.1	12.2	6.8	13.2	8.0	10.4	.0	14.6	13.6	13.5	13.5	14.4
GREEK	15.3	13.9	11.4	14.4	13.0	10.8	14.6	.0	14.6	13.7	13.8	14.8
FRENCH	13.2	15.0	13.2	14.4	14.0	12.8	13.6	14.6	.0	14.3	16.7	15.1
OLD NORSE	15.6	14.2	13.2	14.0	12.6	14.6	13.5	13.7	14.3	.0	15.2	13.2
ENGLISH	14.5	12.8	10.6	14.4	11.0	12.3	13.5	13.8	16.7	15.2	.0	14.9
OTHER	13.6	15.3	13.9	13.1	13.4	15.8	14.4	14.8	15.1	13.2	14.9	.0

(Legend: LEXICAL WORD – number of lexical words; VERBS - number of verbs per title; NOUNS - number of nouns per title; ADJECTIVES - number of adjectives per title; LATIN - number of words/terms of Latin etymology per title; GREEK - number of words/terms of Greek etymology per title; FRENCH - number of words/terms of French etymology per title; OLD NORSE - number of words/terms of Old Norse etymology per title; ENGLISH - number of words/terms of English etymology per title; OTHER - number of words/terms of etymology in other languages per title)

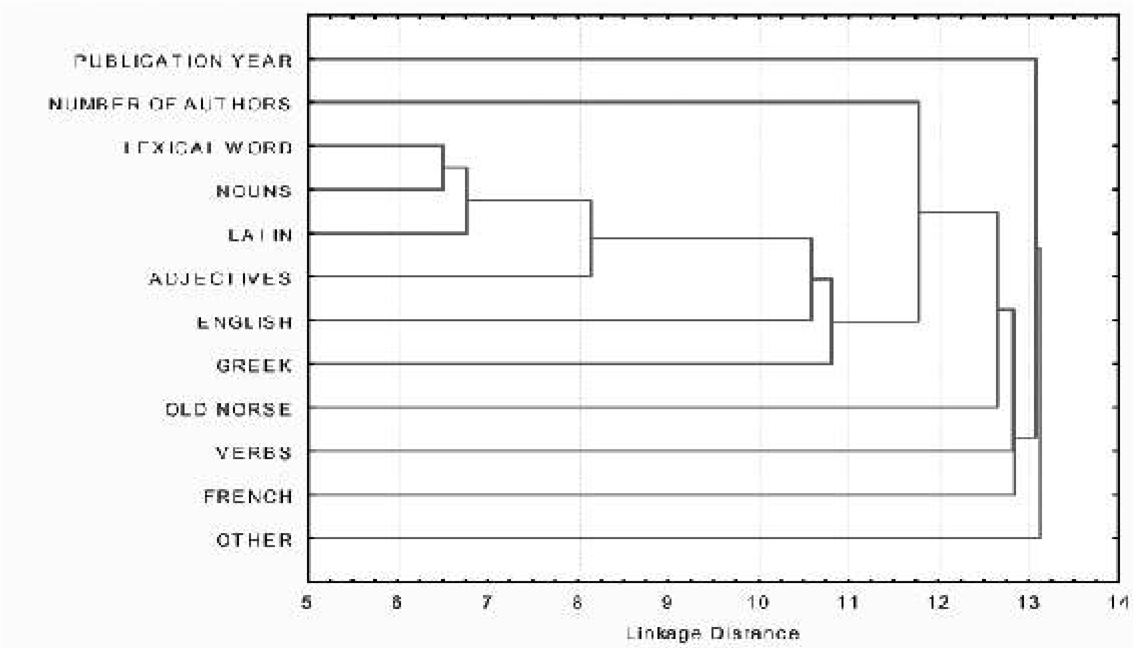

Figure 4. *Single linkage – Euclidean distance (Legend: LEXICAL WORD – number of lexical words; VERBS - number of verbs per title; NOUNS - number of nouns per title; ADJECTIVES - number of adjectives per title; LATIN - number of words/terms of Latin etymology per title; GREEK - number of words/terms of Greek etymology per title; FRENCH - number of words/terms of French etymology per title; OLD NORSE - number of words/terms of Old Norse etymology per title; ENGLISH - number of words/terms of English etymology per title; OTHER - number of words/terms of etymologyin other languages per title)*

DISCUSSION AND CONCLUSIONS

As regards the number of articles published, the results showed that this number increased after 2004 which may be interpreted either as the result of increased interest of scientists for artistic gymnastics-related topics in the last five years, as the result of the increased number of journals dealing with gymnastics-related issues, or as a combination of the two.

According to the results in this analysis, the largest number of articles was found in journals whose domain is biomechanics. This is in favour of the existence of an epistemic community that devotes its knowledge and effort to the artistic gymnastics-related issues. Secondly, since there are also journals whose domain is broader and that consider a certain subject matter from various aspects, it is obvious that interdisciplinary approaches link different epistemic communities that have succeeded in combining their bodies of knowledge to research into the topics that, when observed from various angles, shed new light on certain subject matters.

The number of authors per article may be considered as a certain recurring pattern, i.e.r most articles were written by two or three authors. According to Wray (2002), one author per article is the characteristic of papers written within the scope of social sciences. However, collaboration in scientific work has its justification in its significant causal role for the success of scientific communities in the realization of epistemological goals, i.e. the formation of knowledge and the efficiency of such work (Wray, 2002). Also, it is almost impossible for only one person to realize an experimental research (Viskić-Štalec, Omrčen, & Štalec, 2007).

Therefore, the conclusions regarding the number of authors of papers written within the analysed literature must be taken with a grain of salt. In accord with empirical-data-based conclusion making, the philosophy of science postulates in its positivist approach variety, that observation-based conclusion making yields law-like regularities between observations which are then projected into the future (Timms, 2008), i.e. the observation-based conclusions must have their predictive value. However, Timms (2008) further emphasizes that such an approach is questionable in application because it deals with people rather than inanimate their behaviour. However, from the realist point of view, which focuses on finding causal factors that form the conclusions, it could be reasoned that nowadays success in sport is the result of many different people, and many different factors, contributing with their knowledge and effort to the development of a successful athlete in any sport, hence also in artistic gymnastics, and collaboration of expertsobjects and the potential of people is to changeseems to be the only possible way to achieve this goal. That is the reason why research into various issues in sports is done by teams of experts which is consequently manifested in scientific and professional articles being written by more than one author. Therefore, the predictive value of the fact that artistic gymnastics-related articles considered in this study were written by more than one author is related with the state-of-the-art of competitive sports.

Regarding the relationship between *publication year* and *number of authors* which showed significant differences in the number of authors by publication year it was found that there were years in which the number of articles written by only one author dominated. With one exception, these can be identified as the Olympic years and the reason for the obtained results is very likely that in the Olympic years many researchers focused on actual competitions and not so much on scientific research which followed thereafter. This conclusion seems to be logical; however, there may be other reasons not perceptible in this analysis for the decreased number of authors by publication years.

The continuous rather high number of words of Latin and Greek origin in the titles substantiates the reasoning regarding one of the characteristics of sport-specific terminology on the one hand and the scientific style of writing on the other. Both constantly operate with a substantial number of words/terms of Latin and Greek origin.

As for the words/terms found in the analysed titles, among the oldest words of Greek origin were *diet* which started to be used in the English language between 1175 and 1225 (*Random House Webster's Unabridged Dictionary*, 1999), *giant* which started to be used around 1250 AD (*Random House Webster's Unabridged Dictionary*, 1999), *mass* and *history*, and among the youngest the words *hormone,* which started to be used in English around 1900 (*Random House Webster's Unabridged Dictionary*, 1999), and *peripheral*, *aesthetic*, *biology* and *technique* whose usage in the English language started after 1800 (*Random House Webster's Unabridged Dictionary*, 1999).

Among the words that can be traced back to Latin there also were some rather 'old' words such as *use* and *image* that came into use in thEnglish language at the end of the 12th century, *element*, *number* and *pain* around 1250s, as well as *pattern* and *level* at the beginning of the 14th century (*Random House Webster's Unabridged Dictionary*, 1999).

It is well known that the English language originated from Anglo-Frisian and Lower Saxon. The first line of Latin influence occurred even before the time the ancestral Saxons came to Britain from continental Europe. Apart from being closely related to Old Frisian, Old English was strongly influenced by Old Norse spoken by the Vikings who repeatedly invaded the territory of Britain.Vikings who repeatedly invaded the territory of Britain.

Most words of Latin and Greek origin together with French words entered Old and Middle English through French, again due to the invasions of foreign conquerors, this time the Norman French, the mixed Scandinavian and French people who conquered England in the year 1066. These words came into use approximately at the end of the Middle Ages. At that time Latin was the diplomatic as well as scholarly language used throughout Europe, and many Latin words entered Old English either directly or indirectly through French. Latin extended all over Europe and it was at the beginning of the Middle Ages that Biblical Latin became current in the western parts of Europe. After the Norman invasion in 1066 the English language was under the influence of the Norman language, also termed *Old Norman* and *Anglo-French*. However, two things were important here regarding the existence of many Latin words in the English language. First, it is from Vulgar Latin that the Romance languages (including French) developed, and consequently, many words used in Old French were derived from classical Latin. Secondly, the runic alphabet was replaced by Latin alphabet.

At the dawning of Renaissance many Latin and Greek words streamed into the discourse of the new concept of scientific research. Greek and Arabic texts were translated into Latin and original Latin texts were studied as well.

The 1990s saw the skyrocketed usage of the world computer network that, quicker than anyone could expect, established itself as the global communication network used in all areas of the society. Scientific research results became accessible to more people than ever. Science demanded a scientific language common and understandable to all who worked within the contemporary scientific paradigm and the words of Latin and Greek origin played an important role in creating the terminologies of various scientific disciplines.

The number of words/terms of Latin and Greek origin in scientific texts is undoubtedly large. Such a large number of Graeco-Latin words are the result of the fact that gymnastics is incomprehensible without the knowledge of human anatomy, physiology and biochemical processes. Since these three scientific disciplines comprise the vast domain of medical sciences, which use a large number of terms of Latin and Greek origin, the utilization of a large number of terms of these origins in language from scientific research in gymnastics seems to be logical.

Significant differences found in the number of words of Latin etymology used in the titles as regards the varying number of authors may be explained by the reason that what links the smaller number of authors is primarily the compact lexicalstructure dominated by two word classes (nouns and adjectives) of Latin, and then the words of English and Greek origin. In other words, when more authors are included the writing style, i.e. its lexical characteristics, starts to dissolve. The writing style of teams consisting of fewer authors is manifested in a coalescent expression. Since no such differences were found for the number of words/terms of Greek origin per title in relation to the number of authors, it is obvious that what differentiates the writing styles is the number of words/terms of Latin etymology.

Another characteristic of language used in titles that should be emphasized is its compactness and informativeness. The type of language used in them is termed *block language*, i.e. it is a kind of language characterized by the omission of unnecessary words in such a way that only the relevant data (denoted by words) are retained. As it is evident from the results, the vocabulary used in the titles is characterized by the usage of lexical words, predominantly nouns, followed by adjectives and verbs. Obviously, nouns were the most frequently used word class, which are a word class that can be organized into hierarchical relations (Marinellie & Chan, 2006). In other words the meanings of nouns tend to be stable and predictable (Marinellie & Chan, 2006), therefore, convenient for accurate expression. On the other hand, the verbs do not have well-organized structure and their meanings are not as stable or predictable as those of nouns (Marinellie & Chan, 2006). Further, most words used in the analysed titles may be categorized as low-frequency words taking into account the general language. Unlike general language in which low-frequency words often result in poorer definitions compared to high-frequency words that often result in better definitions (Marinellie & Chan, 2006), in scientific and technical language where some low-frequency words may be considered to be more frequent, it is mandatory that they be accurately and unambiguously defined to avoid misunderstanding. Although function words were also used in the titles, their number, which was more than two times smaller than the number of lexical words, denotes precisely the block-language style in which the analysed titles were written.

Much of the vocabulary type, i.e. of the type of discourse used in the titles can also be attributed to the academic style of writing. There is a list of academic words, i.e. of words that are most frequently used in academic writing, which was compiled by A. Coxhead (1998, 2000). Coxhead (1998, 2000) devised a list of academic words containing 570 word families by compiling the body of academic words used in science, law, arts and commerce, and consequently many authors have stated that this *Academic Word List* (AWL) plays a significant role in academic writing (e.g. Vongpumivitch, Huang, & Chang, 2009). Research has shown that the knowledge of words found on this list is necessary for academic writing (Chung & Nation, 2003; Mudraya, 2006; Chen & Ge, 2007). When we compared Coxhead's AWL with the list of lexical words from our analysis, we found out that approximately 10% of all lexical words – and roughly 7% if both lexical and function words were taken into account – from the analysed titles were words from Coxhead's *Academic Word List*. This concurs with Coxhead's findings, as well as with findings of Nation (2001, p. 17) who confirmed Coxhead's thesis on the existence of a set of words that characterize academic discourse. The percentage of *academic words* in conversational style, according to Nation (2001, p. 17) is about 1.9%, in fiction 1.7% and in newspapers 3.9%, whereas in academic texts the percentage of academic words increases to 8.5%. It is therefore obvious that, concerning the selection of academic words, the style of writing of gymnastics-related scientific texts, i.e. their titles, conforms to the generally accepted academic writing style. The value of approximately 10%, i.e. 7% of academic words used in the titles is naturally not the same as the one determined by Nation, however, this is probably due to the fact that language used in titles is always, or tends to be, devoid of redundant words, so that these percentages would probably be slightly different if full texts of articles were considered.

Regarding the interpretation of the results of cluster analysis, it would not be altogether correct to conclude that scientific discourse of the gymnastics-oriented epistemic community is as a rule dominated by the use of nouns and adjectives because the analysis in this paper did not address the full texts of articles. True, nouns were the dominant word class in the titles; however, this was due to the specific type of language, i.e. block language used in them. Still, there is the fact that, in general, scientific texts are dominated by lexical words as well as by words of Latin and Greek etymology. In congruence with the block-language-style of writing the titles, few verbs were used from which only three were the finite forms of the auxiliary verb *to be*. The omission of finite forms of the auxiliary *to be* is also one of the characteristics of block language. The dominance of nouns and adjectives in this analysis could be attributed to the fact that the sample was comprised of titles, and their style is, as already said, specific because the language used in them is the so called *block language* that has its specifics that are not found in the language used in the actual texts of articles. Undoubtedly, the words of Latin and Greek origin were used abundantly and this is one of the characteristics of scientific discourse of texts originally written in English.

The most frequent word class within the set of lexical words were the nouns of Latin etymology. The second most frequent word class used in the analysed titles were the adjectives, and the nouns and adjectives in the analysed titles were, apart fromLatin, also of English and Greek origin. The number of authors per title was rather distantly connected with the usage of nouns and adjectives from Latin, English and Greek origin. In other words, with the increase of author's number, the type of vocabulary, i.e. style of discourse used in the titles changed from a rather compact style to the style which contained a broader range of word classes originating from languages other than Latin, English and Greek.

Almost two thirds of all lexical words used in the titles were either of Latin or Greek origin. Adding French, Old Norse and *Other* languages to this calculation, the number of words whose origin is not in the English language, meaning 80%, amounted to more than two thirds of the total number of lexical words used in the titles. Whereas the usage of words from French, Old Norse, Old Danish, etc. origin may be attributed to the transfer of words across languages due to various commercial, political and migratory reasons, the reasons for the usage of the words of Latin and Greek origin are to be sought in the type of discourse used in sciences in general and that can be put under the same common denominator – *scientific*. Therefore, and compared to the Coxhead's AWL, once again it was confirmed that there is a set of words shared by scientific disciplines whose usage determines the writing style of the whole academic community. This broad epistemic community can be subdivided further into other smaller ones characterized by the usage of vocabulary typical only for a particular community – in this case the gymnastics-oriented epistemic community. This is evidenced by the usage of terms that are typical for the epistemic community, which is in the focus of the analysis in this paper. In other words, an additional characteristic of the analysed titles were the words/terms that are even more specific than the so called academic words. These words can be put under the same common denominator of *technical terms* that, in combination with the academic words, comprise the vocabulary of the analysed epistemic community. If the terms *gymnast* and *gymnastics* itself, which occurred 76 times in the titles, are considered, it is clear that they amount to 8.5% of all lexical words used in the titles, enough to determine the vocabulary of epistemic community concerned. If the incidence of the word *artistic* (28 times, i.e. 3.1% of all lexical words) is added, the resulting 11.7% mean that the presence of only four words could be used to describe the epistemic community in question. It is also clear that if other technical terms used in the titles were added to the equation, e.g. asymmetric/uneven bars, parallel bars, giant circle, dismount, etc., the academic vocabulary type could be understood as being comprised of scientific and technical terms. Hence the epistemic community of artistic gymnastics-related researchers can be identified both by the academic vocabulary used by all members of the scientific community and by itsspecific vocabulary. The more specialized an occupation, the more technical its vocabulary. Also, the longer an occupation belongs to an established tradition; more specific linguistic rituals will be accepted by its members as discourse criterion (Crystal, 2002, p. 370). To avoid ambiguity, the terms used by one occupation must be standardized. The process of standardization of terms within the system of concepts then results in creating a terminological system, i.e. the terminology of the activity in question.

The existence of typical vocabulary is in accordance with the fact that terminology belongs to the set of basic epistemological characteristics of each science, and that it should be considered with outmost care in order to validate scientific communication.

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LOW BACK PAIN AND THE POSSIBLE ROLE OF PILATES IN ARTISTIC GYMNASTICS

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Systematic scientific review

Abstract

Low back pain is one of the commonest sites of pain in gymnasts. This pain may accompany well defined anatomical abnormalities of the spine or be present without significant skeletal abnormality. Skeletal abnormalities correlate with age and hours of training per week implicating that spinal injuries in gymnasts are "training-dose" related. We give an overview of the studies reporting on the incidence and prevalence of spinal injuries and low back pain in artistic gymnastics. The origin of low back pain is described and analysed. Pilates is an increasingly popular system of body-stabilising exercise. Its main principles are devoted to activation of the muscles contributing to spinal stabilization. It was used as a rehabilitation method for a lower back problems and was shown to be effective and of good subjective acceptance in the general population, whereas specific studies in the artistic gymnastics are lacking. According to the studies with training programs implementing similar lower-trunk stabilizing principles as Pilates, gymnastics couches may be encouraged to implement this kind of exercise for prevention and treatment of chronic low back pain in gymnasts.

Key words: *sport, injury, training, spine, rehabilitation, prevention*

INTRODUCTION

It is becoming increasingly difficult to achieve top level results in artistic gymnastics. As the sport disciplines become increasingly professionally planned and thoughtfully guided, new methods and resources are being increasingly introduced which prevent random and coincident factors to influence the training process (Čoh and Čuk, 1995). Achievement of top-level results in artistic gymnastics is dependant on several factors ranging from implementation of scientific findings on one hand to efficient prevention of injuries on the other. Sport injuries can represent a serious obstacle in achieving goals in Artistic Gymnastics. To the gymnasts chronic pain syndromes of which low back pain is one of the commonest, are a classic example of sport related injuries (Micheli, 1985; Caine et al., 1989; Tertti, 1990; Konermann and Sell, 1992; Wadley and Albright, 1993; Lohrer and Arentz;2001; Bono, 2004; Caine and Nassar, 2005; Bennett at al., 2006; McCormack et al., 2006; Kraft et al., 2007; Harringe et al., 2007a; Harringe et al., 2007b; Marini et al., 2008; Vrable and Sherman, 2009).

The incidence of low back pain is increased with increment in hours of training per week (Goldstein et al.,1991), therefore it is of paramount importance, to implement in the training process new methods and exercise programs, which are able to reduce and prevent the development of chronic back pain.

PILATES - A METHOD OF SPINAL STABILIZATION

Pilates, a special method of training, is a system of exercises developed by Joseph Pilates (1880-1967) during World War I (Lately, 2001). Its popularity is growing worldwide in the last two decades. It is popular in all areas of fitness (Segal et al., 2004; Jago et al., 2006) and rehabilitation (Smith and Smith 2004; Johnson et al., 2007; Kaesler et al., 2007). Pilates is a method of bodystabilization, which combines strength and stretching exercises in a special way, always following a set of basic principles. In the published literature several sets of basic principles are defined (Siler, 2000; Craig, 2001; Ungaro, A. 2002; Merrithew, 2003; King, 2004; Herman, 2004) all striving to adequately teach a correct execution of Pilates exercises. A correct execution of exercises includes activation of deep trunk stabilizers (transversus and obliquus abdominal wall muscles) at the same time with the muscles of pelvic floor and multifidus which enables a better stabilization of lumbar spine. This is an exercise system, which, correctly executed, prevents and diminishes lower back pain (Donzelli et al., 2006). In 2008, the study of deep trunk stabilizers' activation in Pilates exercise was published which was aimed to assess activity of transversus and obliquus internus abdominal muscles during classical Pilates exercises performed correctly and incorrectly (Endleman and Critchley, 2008). The activation of muscles was assessed using an ultrasound scanning. Strong and consistent activation of trunk stabilizers was found during the correct exercise execution, which was absent when exercises were incorrect. This finding confirms the efficiency of Pilates in trunk and spinal stabilization.

SPINAL INJURIES AND LOW BACK PAIN SYNDROMES IN ARTISTIC GYMNASTICS

Low back pain is an extremely common complaint in competitive gymnasts, and these athletes are at risk for multiple potential structural injuries to the spine. Low back pain can have an acute presentation, which most often represents muscle and ligament strains with transient pain diminishing in several days or weeks. Alternative presentation is a more chronic, persistent or recurrent pain syndrome, which is a greater drawback for the gymnast, since it can result in significant impediment iny the training process. Of particular concern among gymnasts is spondylolysis (Kennedy1994; McCormack and Athwal, 1999; Guillodo et al., 2000; Mannor and Lindenfeld, 2000). Of particular concern among gymnasts is spondylolysis (Kennedy1994; McCormack and Athwal, 1999; Guillodo et al., 2000; Mannor and Lindenfeld, 2000).

Caine et al., 1989 performed an epidemiological survey in female gymnasts, in which 43 out of 50 included gymnasts suffered from a cumulative number of 147 injuries in a one year period. Graduate onset of pain was a presenting sign of 56% of injuries and lower back was one of the most commonly affected regions.

The great prevalence of spine injuries in competitive artistic gymnastics was reported already in early studies of this problem (Goldstein et al., 1991). In this study the magnetic resonance imaging (MRI) was used to demonstrate spinal abnormalities. They were found in 9% pre-elite, 43% elite and 63% olympic level gymnasts and in only 16% of swimmers. The spine abnormalities were predicted by age and hours of training per week which suggests that spine injuries in gymnastics are »dose« related, with 15 hours of training or more per week suggested as a threshold of significantly increased risk.

THE ORIGIN OF BACK PAIN

The most common injuries of spine resulting in back pain can be in simplistic terms classified into four general types. The first type of pain is the result of acute overload and microtrauma of spinal elements resulting in typical strain-type of pain. This pain and soreness comes from the spinal muscles and ligaments which are overstretched and injured and usually goes away within a few days with appropriate resting and lowering of activity.

Second class of back pain injuries comes from the rupture of intervertebral disc with or without herniation of the jelly nucleus pulposus through the crack. This type of hernia injury causes lumbar pain and sciatica (pain radiating down the buttock and the posterior part of the leg) and is associated with the irritation of and the pressure on the spinal nerve roots. This type of injury may arise with sudden twisting or bending movements of the spine.

Third type of spine injury is the consequence of hronic wear-and-tear type of degenerative injury. In this process intervertebral discs shrink, this causes the parts of facet joints to increasingly rub againts each other (figure 1). With time the degenerative process results in osteoarthritic bony formations (spurs) which encroach on the spinal canal and narrow it causing spinal stenosis. Finally, the fourth

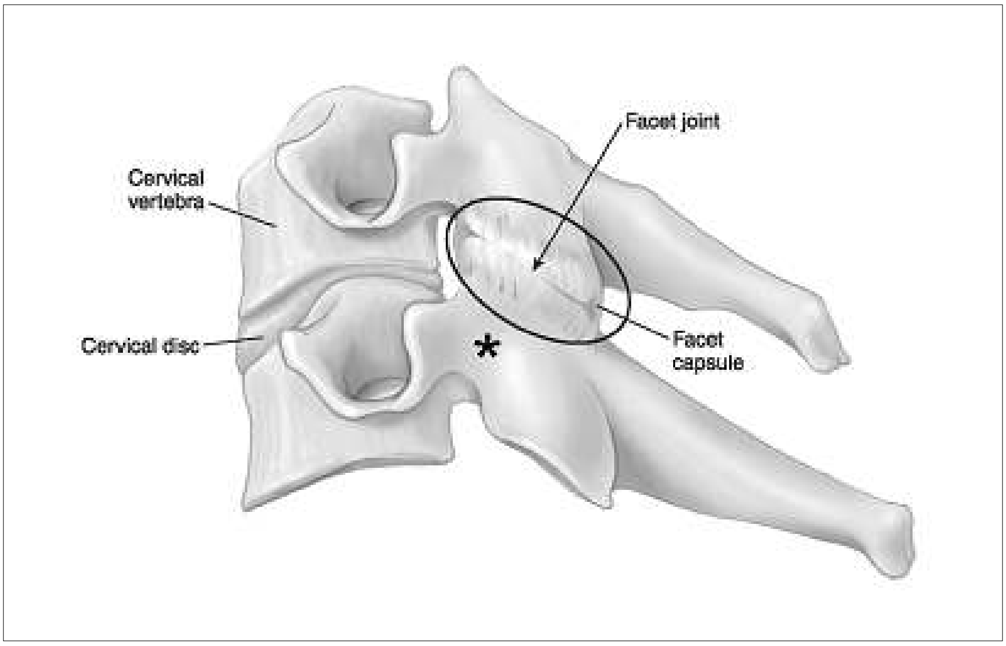

Figure 1. *The anatomy of intervertebral discs and facet joints.*

typical type of spine injury is spondylolysis and consequent spondylolisthesis. Spondylolysis is a condition where there is a disconnection in the bony part of the vertebra between both facet articular surfaces (see the asterisk in figure 1). This may be the consequence of a stress fracture and is typically found in the lower back (fifth lumbar vertebrae). When this causes a slipping of one vertebrae over the other the resultant misalignment of the spine is called spondylolisthesis (figure 2).

In the study on olympic-level female gymnasts spondylolysis and spondylolisthesis were found in 3 out of 19 gymnasts, and were present only in the subgroup with the current ongoing low back pain (Bennet et al., 2006). Similarly to the above mentioned results of Goldstein et al. (1991), the abnormalities of the spine in the study of Bennet et al. (2006) were detected in approximately two thirds of olympic-level gymnasts. In the contrast to this two reports, in the study on elite horse vaulters only slight degenerative changes of the lumbar spine were found with MRI scanning, although 85% of included vaulters reported back pain and 75% reported daily back pain (Kraft et al., 2007). Therefore it may be concluded from this opposite findings that the presence of back pain

Figure 2. Spondylolisthesis. (Note the misalignment of the fifth lumbar vertebrae above the sacrum, which is the result of slipping forward of the fifth lumbar vertebrae).

in gymnast is not a necessary consequence of a significant pato-anatomical derangements of the spine. In this case the value of appropriate preventive training such as Pilates may be especially high. However persistent or major back pain in a gymnast must be recognized by their trainers as a possible sign of significant spinal injury (such as spondylolysis) and appropriate medical help must be sought.

THE ROLE OF PILATES IN PREVENTION AND TREATMENT OF LOWER BACK PAIN

Pilates as a form of body stabilizing exercise may be used in the rehabilitation of chronic low back pain. Through the activation of lower trunk stabilizers it may improve the spinal protection and enable one to neutralize the influence of improper posture and repetitive strains on the development and persistence of lower back pain. The proof of this presumption came in 2006, when three randomized controlled trials were published on the efficacy of Pilates-based therapeutic exercise in the rehabilitation of low back pain. However, it is important to mention that randomized clinical studies on this subject began to be published as of 2006 (La Touche et al., 2008).

In the first study by Rydeard et al., (2006), 39 subjects with chronic low back pain were randomized to the 4-week Pilates program group or the control group without specific training program. After the 4-week training the subjects in the intervention group had a significantly lower functional disability score (2.0 vs 3.2) and a significantly lower pain intensity score (18.3 vs. 33.9). The benefit in disability score was maintained even after 12 months. In the second study by Donzelli et al. (2006), 43 subjects with lower back pain were randomized to the classic "Back school" rehabilitation program or the Pilates based rehabilitation program. The length of each program was 10 daily sessions. Pain and disability scores similarly improved in both group with the Pilates group showing somewhat better subjective response to treatment. In the third study by Gladwell et al. (2006), 49 subject with chronic non-specific low back pain were randomized to contol or Pilates group. The Pilates group undertook a six week program of Pilates and after that both groups continued with normal activity. Improvements were seen in the Pilates group post-intervention withincreases in general health, sports functioning, flexibility, proprioception and the most important a decrease in pain. All other articles searched using SienceDirect and ISI Web of Knowledge confirmes the role of Pilates in prevention and treatment of low back pain (Sekendiz et al., 2007; Da Fonseca et al., 2009; Levine et al., 2009; Curnow et al., 2009). The terms used for the search were "Pilates" and "Low back pain".

The rehabilitation of gymnasts with lumbar injuries is poorly studied. The related literature would support incorporating the concepts of dynamic lumbar stabilization and sport-specific training into rehabilitation programs of low back pain (Standaert, 2002). In 2007a, Harringe et al. published the results of controlled intervention study, in which 42 young female teamgym gymnasts were randomized to specific segmental muscle training program of the lumbar spine. Gymnasts in this training program reported significantly less number of days with low back pain as compared to baseline, whereas no difference was observed in the control group. 8 gymnasts in the intervention group (53%) became pain free. Another study examined advanced level female artistic gymnasts and the most common pain sites were the ankle and low back (Marini et al., 2008). In this study, the specific preventive-compensative training program in the warm-up and cool-down sessions was tested for reduction in pain syndromes. Besides other things this training program was reported to implement treatment of shortened muscle chains and mobilization of back using fit-ball (which can be found also in individualized Pilates programs). After intervention, low back pain was reduced in all pain severity subgroups with the greatest benefit in the severe pain subgroup.

In artistic gymnastics there are no controlled randomized studies to examine the benefit of Pilates exercise on the prevention or treatment of low back pain. However in recent years, some data has accumulated which may allow extrapolation of the usefulness of Pilates also to the field of artistic gymnastics. According to presented results and the widespread popularity of Pilates it is possible to expect that in future also the studies examining the specific effect of Pilates exercises in the prevention of low back pain will emerge in the field of artistic gymnastics.

CONCLUSION

Chronic pain syndromes represent a significant problem for the advanced and elite level gymnasts. Low back pain is one of the commonest sites of pain. This pain may accompany serious anatomical abnormalities of the spine or be present without significant skeletal abnormality. Therefore, the gymnast with repetitive and disability-causing pain should be medically examined to exclude serious spinal abnormalities which were shown to be possibly present even in elite-level gymnasts (such as spondylolysis and spondylolisthesis). We presented data from studies, which show that skeletal abnormalities correlate with age and hours of training per week implicating that spinal injuries in gymnasts are "training-dose" related. It is left for future studies to examine to what extent the damage gained in the active training period would predispose gymnasts to the spinal medical problems in later life. As regards the preventive and rehabilitation methods, Pilates was shown to be effective and of good subjective acceptance in the general population, whereas specific studies in the artistic gymnastics are lacking. According to the studies with training programs implementing similar lower-trunk stabilizing principles as Pilates, gymnastics couches may be encouraged to implement this kind of exercise for prevention and treatment of chronic low back pain in gymnasts.

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