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Science of Gymnastics Journal (ScGYM®)

Science of Gymnastics Journal (ScGYM®) (abrevated for citation is SCI GYMNASTICS J) is an international journal that provide a wide range 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, pedagogical 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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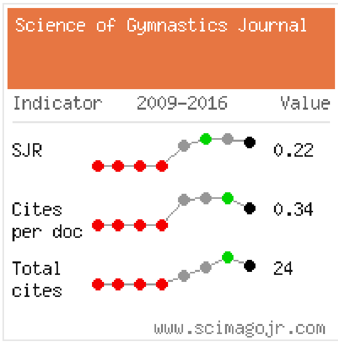

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CONTENTS

EDITORIAL

Dear friends,

In Montreal, the World Championships in artistic gymnastics have just ended. We saw some excellent gymnastics and, unfortunately, also some injuries of most decorated gymnasts (Uchimura, Japan, and Iordache, Romania). We are still looking forward to an upgrade in the quality of gymnastics and improvements in the health status of our athletes. Hence, dear fellow researchers, please do further research projects to improve our gymnastics!

With your creative work we have published 153 original articles so far and hope that they have improved our practice.

On our Editorial Board we have a new member, **Thomas Heinen, Ph.D., from Germany**. In the last years he has regularly collaborated with the Journal by contributing many articles, mostly related to motor learning and motor control. Welcome aboard, Thomas!

The first article in the current issue is about Aljaž Pegan, a high bar specialist and a gymnastics senior. Andrej Kunčič and Jože Mešl (Aljaž Pegan's coach) prepared an analysis of variations in Pegan's long-lasting career. The article is partly a historical overview and partly an overview of the training theory. It answers the question how to stay on top despite changes in the Code of Points.

The second article comes from authors from three countries: Almir Atiković of Bosnia and Herzegovina, Sunčica Delaš Kalinski of Croatia and Ivan Čuk of Slovenia. We explored the age trends in artistic gymnastics from 2003 up to 2016. Dr Bruno Grandi, former FIG President, can be proud of his work as gymnasts' age is on the increase.

The third article is from Linda Hennig from Germany with focus on mental representations in the evaluation of gymnastics skills in students of physical education. It brings an interesting perspective on motor learning.

The fourth article is from Iranian researchers Ramin Beyranvand, Rahim Mirnasouri, Saeid Mollahoseini and Sadegh Mostofi who looked into the functional stability of rounded shoulder in gymnasts and non-gymnasts. It provides another proof that we need to plan training loads carefully.

The fifth article comes from Greece; authors George Dallas Alexandros Mavidis, Costas Dallas, Sotris Papouliakos compare postural stability and effects of ankle sprain injuries between male and female gymnasts. Perhaps it would be a good idea that male gymnasts do some conditioning on the beam as well as females?

The last article comes from Germany. Katja Ferger and Michel Hackbarth developed a new system to evaluate the time and place of take-off/touch-down on the trampoline. It is something new and requires knowledge of technology, acrobatics, judging and science to fulfil the competition evaluation requests. Their device could make judging much better in the sense of validity, reliability, objectivity and discrimination.

Anton Gajdoš prepared a new contribution to the history of gymnastics, refreshing our memory on Juriv Titov, former FIG President.

Just to remind you, if you quote the Journal: its abbreviation on the Web of Knowledge is SCI GYMN J. I wish you pleasant reading and a lot of inspiration for new research projects and articles,

Ivan Čuk
Editor-in-Chief

In Bratislava (Slovakia) Slovak Olympic Committee – Slovak Olympic and Sport museum's collection prepared exhibition, opened in September 2017. Prof. Anton Gajdoš showed his collection.

ALJAŽ PEGAN GYMNASTIC RESULTS DEVELOPMENT AT WORLD CHAMPIONSHIPS

Andrej Kunčič[1], Jože Mešl[2]

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Original article

Abstract

In article we overview 19 years of a 33 year long sporting career of the gymnast Aljaž Pegan. His scores, ranks and exercises on the horizontal bar are presented for each World Championship. Exercises are further broken down into individual elements and descriptions of those elements. They are presented in accordance with the Code of Points published by Federation International Gymnastics, which was in force for a particular four-year period, and a theoretical comparison was made, taking into account all the changes and adjustments, with the Code of Points 2013-2016. Additionally, breakdowns of the seven Codes of Points for the horizontal bar which were in force in the period from 1989 to 2013 are also shown. Adaptation to the changing criteria of the Code of Points can be seen in the exercises through upgraded elements, which Aljaž could grasp due to his exceptional knowledge of basic motor structures such as: free hip circles, giant swings, flights and elements in double el-grip. During his career Aljaž and his coach invented two unique elements that bear his last name in the Code of Points, Pegan on the horizontal bar and on the parallel bars. His greatest success was at the World Championship in Melbourne, Australia in 2005, where he became the World Champion on the horizontal bar.

Keywords*: man artistic gymnastics, horizontal bar, result development, Code of Points.*

INTRODUCTION

The sporting career of Aljaž Pegan began in 1980 in Ljubljana when he was five years old. During his career Aljaž had two coaches. The first one was Boris Pavliha with whom he trained for six years. His second coach was Jože Mešl and together they trained at Partizan Trnovo, until Aljaž's 39th birthday. Aljaž ended his active participation on his birthday 2nd June, 2013 at the Slovenian Cup in Ljubljana, where he was second (Bedenik, 2013).

The influence of Jože Mešl and his alternative approach are the main reasons for Aljaž's rapid development and wide spectrum of gymnastic knowledge. The Mešl’s approach deprived his gymnasts for medals in younger categories, but enabled them a faster leap to join more mature gymnasts. Meaning, gymnasts were quickly enabled to perform in a higher category, next to older and more experienced gymnasts and, where the exercises were more difficult and complex (Bedenik, 2013).

During his career, Aljaž had to perform compulsory and optional exercises on an apparatus. Compulsory exercises were cancelled in 1996, despite the fact that gymnast who had to perform both exercises obtained wider spectrum of knowledge. Through the compulsory exercises he learned new elements, strengthened his base knowledge and thus he was able to effectively adapt to all kinds of changes in the Code of Points later in his career.

His engagement in gymnastics was not without injuries. Three of them were serious, among them two of them were the reason for ceasing competition in an all-around and specializing in parallel bars and a horizontal bar. He had his first injury in 1987 when he broke his leg on a vault, performing »Tsukahara«. In 1997 he suffered from the second injury when he had a terrible fall from the horizontal bar and injured his spine. The injury was one of the main reasons why he had focused only on parallel bars and the horizontal bar in the middle of his career. After this last injury in 2003 when he injured his finger on parallel bars he decided to focus only on the horizontal bar (Bedenik, 2013).

One of the explanations for the oscillation of result could be found in the training conditions. He had spent most of his sporting career training in a gym Partizan / Sport club Trnovo, which is a fairly small (13m x 9m x 5m) and poorly equipped in comparison with gymnastics centers, in which other top ranking gymnasts train. The conditions where he trained are important since he was one of the most elegant and reliable gymnasts, but had problems with a dismount. An element that often took its toll on otherwise perfect exercise. Lack of space and bad training conditions are the main reasons why he could not perfect his dismount - a triple salto backwards, or learn a more reliable dismount - e.g. a double salto backwards stretched with 2/1 turn. Bad conditions that especially effect dismount training include an inadequate landing zone and a low height of the ceiling. Another reason for his unreliable dismount could be attributed to changed orientation in space. Since he trained in a small gym and competed in a much larger hall with a much higher ceiling, he had to reacquire orientation in space at each competition, which made it hard to perform the perfect dismount as was not able to fulfill all the criteria of a good dismount according to Geiblinger and Dowden (2015). If he had perfected or learned a new dismount, Aljaž could have achieved even better results than he already had.

His stamp in gymnastics is seen through the two unique elements he invented with his coach and in the Code of Points bear his last name. The thought of a new element on the horizontal bar with a turn was suggested by his training partner Lojze Kolman when Aljaž was learning the Gaylord element and his position, at the point when a gymnast re-grasps the bar, was high (“Aljaz Pegan makes”, 2014). As Aljaž had a good position in the air and had enough time they added a turn to Gaylord, thus making a new element on the horizontal bar named Pegan (Gaylord with ½ turn). First time he performed it in Budapest on 20th March, 1993 during European championship, and was also noticed in Japanese department of study in 1994 (Nakasone, 2015). The second element named after Aljaž is on parallel bars and is a step up of the Diamidov element. Aljaž had great balance in a handstand on one rail and likewise when performing pirouettes on one rail. When Aljaž put both of these two conditions together, he made a new element on parallel bars (Diamidov with 5/4 turn or more to handstand). Though, Aljaž had performed the element on parallel bars for a quite some time, he saw little motivation to include a hard element with uncertain execution in an exercise since, he had already fulfilled norms for maximum starting value of 10 points. However, the

Code of Points 1997 brought some changes and thus Aljaž had to include his element in the exercise. In the end of the year 1996 Aljaž performed his element for the first time at the international competition and FIG added his element in the Code of Points 1997.

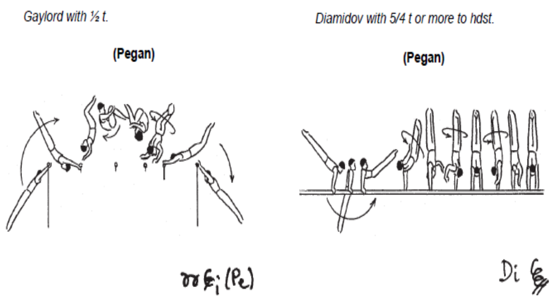

Figure 1. Element Pegan on the horizontal bar and on the parallel bars (FIG, 2013)

Despite the fact that both Pegan elements are a step up from an already existing elements, practicing and performing them is difficult. Being able to perform the base element does not condition the knowledge and performance of an element with extra rotation (turn).

During his long career Aljaž never attended the Olympic Games. He could have qualified for the Olympics Games through the team result, individual ranking in all-around and by becoming an individual apparatus world champion in the year preceding the Olympic Games.

The closest he came to qualifying for the Olympic Games was at the world championship in 1995 in Sabae, Japan. He competed in all-around competition but made a mistake in compulsory exercise and at the end missed the 1996 Olympic Games for bare 0.2 points. Soon after he got injured and continued his carrier only on parallel bars and on the horizontal bar.

Slovenia tried to qualify through team result for the second time at the world championship in 2003 in Anaheim, United States, but the team was not strong enough. Aljaž could have qualified for the Olympic Games on his own by becoming the world champion on the individual apparatus, but he did not qualify for the final event.

Aljaž could have qualified for the Olympic Games by becoming the world champion on the individual apparatus, at the 2007 world championship in Stuttgart, Germany. Unfortunately he came second on the horizontal bar.

Aljaž won his first medal at the national level after two years of training under supervision of coach Boris Pavliha. The period under Pavliha lasted for four more years, from the 1982-1986. During this time he attended and often won competitions at a national level. At the beginning of 1986 he came to Partizan Trnovo to train under Jože Mešl. During 1986 he was a perspective gymnast and attended a federal championship in Priština Yugoslavia where he was 10th. In 1987 he won at the Tournament of Brotherhood and Unity in Yugoslavia where he had competed with the best young gymnasts in Yugoslavia. The following year he became the junior champion of Yugoslavia and in 1989 he was a reserve in Yugoslavian team at the world championship in Stuttgart, Germany. At a junior four nations competition in 1990 in Belgium he almost came into all the finals and the Yugoslavian team was victorious. At the junior European championship in 1991 he was the 12th in all-around competition and the 6th on a horizontal bar. He was also a part of the Slovenian team at the Mediterranean games in France in 1993, where Slovenia was the third and Aljaž was the second on a horizontal bar.

During his career in a senior category he participated in over a hundred international competitions, where he had also achieved his greatest achievements on the horizontal bar.

In his long lasting career Aljaž attended fourteen World Championships in men's artistic gymnastics. His greatest success was at the World Championship in Melbourne, Australia in 2005 where he became the World Champion on the horizontal bar. In the years 2002, 2006 and 2007 he achieved the second place.

In his career he attended the World Cup competitions and won 27 times, became second 14 times and third place 9 times. In the season 2001/2002 Aljaž won at the overall World Cup final, he won the second place twice in the seasons of 1999/2000 and 2009, and in the season 2005/2006 he was the third.

He was twice awarded the European Champion on the horizontal bar, in 1994 and 2004. In 2007 he was the European runner up and in 2000 and 2008 he achieved the third place.

Besides numerous successes and medals Aljaž had received various prizes for which he had been selected among other candidates. The Gymnastic Union of Slovenia chose him as a sportsman of the year in the years of 1999, 2001, 2002 and 2006. Journalism Association of Slovenia chose him for sportsman of Slovenia in the year 2002. Sports Union of Ljubljana chose him for the sportsman of Ljubljana (capital city) in the year 2004.

Although the research of Novak and Čuk (1985) has been written a long time ago (and gymnastics developed severely since then), some aspects and conclusions are still valid. At the beginning of an athlete's career their results are improving, later they are stable and at the end results are getting worse. According to the general rule of development competitive results can be controlled whether our training plan gives adequate results. Authors came to a conclusion that the way of coming up with a score in artistic gymnastics has 3 characteristics, which hardens to put an objective view on result development. Those characteristics are:

- Evaluation is done subjectively. Measure instruments are judges, measure units are scores. Judges' score cannot be as objective as physical units of measurement.
- The perfect score is limited with a maximum score of 10 points (today still for execution only).
- The required content of the exercises varies among competitive categories, especially in difficultness.

Countries all over the world have usually their own competitive systems which consequently imply different competitive categories, making it hard for comparison. The alignment of competitive categories and exercises contents are applied in junior and senior categories and are determined by the International Gymnastics Federation (FIG).

An annual training plan is a tool that guides an athlete through 12 months of training and within those 12 months maximizes physiological adaptation and performance at specific time points, during the main competitions of the year. Within an annual plan some months can vary from the rest of the year to reduce physiological and psychological fatigue, and induce regeneration (Bompa & Haff, 2009).

Periodization divides the annual training plan into smaller training phases, thus making it easier to plan peak performance at the main competition. Within training phases we target biomotor abilities which will allow the athlete to develop the highest levels of speed, strength, power, agility and endurance possible. The annual training is composed with three main phases: preparatory, competition and transition. The transition phase connects annual training plans together and within this phase the main objective is to remove fatigue and allow the athlete to recover, via the use of active rest. The transition phase generally lasts 2 to 4 weeks but it can last up to 6 weeks (Bompa & Haff, 2009).

"Competitions can be classified into two broad categories: (1) major or official competitions and (2) preparatory or exhibition competitions. Major competitions are the athlete's most important competitions (e.g., national championships, world championships, Olympic Games). Preparatory or exhibition competitions are used to test the athlete and attain feedback regarding specific aspects of training" (Bompa & Haff, 2009, p. 195).

"A key condition for gaining planned results over many years of preparation is to figure out a "tree of goals", setting specific tasks subordinate to the main strategic objective of successful performance at the major competitions with appropriate results. The main ones are as follows:

- Creating optimal surplus (technical, tactical, physical, functional and psychological);
- Outstripping possession of new super-complex exercises and on time mastery of the integrated model of the current stage of preparation;
- Ensuring reliable and highly-productive activity in conditions that are more difficult than competition, according to the basic parameters" (Arkaev & Suchilin, 2004, p. 75).

Aljaž had an injury in 1997 which prevented him from competing in all-around competition so he focused only on parallel bars and the horizontal bar. In 2003 after his third injury he focused his career only on the horizontal bar. These are some facts how his annual training plan looked like and how he was able to prepare for major competitions. He trained from Monday to Saturday twice a day. The only exception was Wednesday when he had trained solely in the afternoon. Sometimes he also trained on Sunday mornings. Morning practice was from 10 to 12 am and afternoon practice was from 4 to 7 pm. Throughout the years duration of practices decreased and more attention was given to spatial orientation.

During the transition phase he had a program of exercises and with it he maintained his physical condition. His transition phases usually lasted from the middle of December to 10th of January and from the middle of June to the end of July. The transition phase varied depending on schedule of major competitions.

After each transition phase it took him from 9 to 11 weeks to get into a form. During this time he had problems with his general condition and that was shown in elements reliability and especially in reliability of a dismount. After he got into form he usually needed three competitions to get into a stable competition performance which he could maintain for about a month and during this time his competition performance reached its peak.

Before each competition his weekly training plan was different and for the whole week he trained in leotard, stirrup pants and socks. His weekly training was basically a simulation of an actual competition. He warmed up as he would have before a real competition and then performed one full exercise and after that one more. The first exercise was meant as preliminary competition and the second as finals. After that he practiced only critical sections of an exercise to gain reliability and stability.

Through years of competitions element Pegan had a huge impact on Aljažs' Pegan career. Pegan on horizontal bar became a trademark of Aljaž Pegan and that also gave him a slight advantage over other gymnasts in the eyes of the judges. Vlasios Maras was the only gymnast who was successfully executing element Pegan on horizontal bar and also upgraded it to pike Pegan

The purpose of this analyse is to write a historical record about one of the most successful gymnast on the horizontal bar, Aljaž Pegan. Display competitive results and rankings on the horizontal bar at World Championships and to show changes of rules for the horizontal bar, which occurred in the Code of Points.

Code of Points

The Code of Points for MAG in 1989, 1993, 1997 and 2001, when the perfect score was 10 points, are presented with minimal standards by which exercise achieved a maximum start value of 10 points. Minimal standards were defined with an appropriate number of elements of various difficulty value parts.

The following element groups in the Code of Points 2001, 2004, 2006, 2009 and 2013 were (FIG, 2013, p. 123):

I. Long hang swings with and without turns.
II. Flight elements.
III. Elements near the bar (in bar elements).
IV. El-grip and dorsal hang elements and elements performed rearways to the bar.
V. Dismounts.

Element group requirements fall under special requirements in the Code of Points (FIG, 2001), and fulfilling each group requirement provided 0.2 points to a total of 1 point which can be achieved in this section. To fulfill an element group requirement, a gymnast had to perform an element at least B value part and C value part for the dismount.

In the Code of Points coming after the one in 2001 element group requirements had a similar role, however they do not fall under special requirements but as an addition to the difficulty base value. Maximum points a gymnast can acquire in element group requirements is 2.5 points, to receive 0.5 points a gymnast has to perform at least one element from each element group. However there was a requirement that the dismount had to be of value part D to receive 0.5 points. In case the dismount is not of correct value part the following rule applies (FIG, 2013, p. 24):

- A or B value dismount +0.00 p. (not fulfill requirement)
- C value dismount +0,30 p. (partial requirement value)
- D or higher value +0,50 p. (full requirement value)

In the period when the Codes of Points 1989, 1993 and 1997 were in force, a gymnast may have performed every element twice in his exercise, however only if those elements and connections were not eligible for bonus points. In case that any element was performed more than two times there was a deduction rule which changed over the years.

Repetition rule changed in the Code of Points (FIG, 2001, p. 22) in perspective to previous ones:

- No element (same Code Identification Number) may be repeated for difficulty credit or for Bonus Points. This applies also to elements repeated in connections.
- No element (same Code Identification Number) is permitted to contribute to the Start Value.
- No element (same Code Identification Number) may be performed three times in direct succession. The A-jury will deduct 0.20 points or each appearance of three such elements in direct succession.

In the Code of Points 2006, 2009 and 2013 an element may be repeated, however a gymnast will not receive any value for it (FIG, 2006, 2009 and 2013). »No element (same Code Identification Number) may be repeated for difficulty credit or for Connection Points. This applies also to elements repeated in connections« (FIG, 2013, p. 25).

The score of 10 points was structured with the next four sections:

- Exercise base value
- Exercise execution
- Special requirements
- Bonus points

A specific number of points may be achieved in each section, however number of points varies a lot through the Code of Points. A gymnast had the most impact on bonus points, which he could collect by connecting elements of specific value and thus making his exercise worth 10 points. Bonus points are a scoring factor with which a better comparison is made between exercises. Different possibilities for achieving bonus points will be presented for each Code of Points separately in the following tables.

Special requirements are one of the four sections of the score structure. A gymnast may obtain a specific number of points for this section, however, the number of points varies a lot through the Code of Points. Each apparatus has its own special requirements and they are an essential part to achieve a maximum start value of an exercise. These essential parts cannot be replaced with another element from a different element group and a gymnast cannot fulfill two special requirements with just one element.

The following special requirements for horizontal bar applied in the Code of Points 1989, 1993 and 1997 (FIG, 1997, p. 123):

- An element with both hands in el-grip or in hang rearways through the lower vertical (minimum B).
- An element with grip release and a definite visible flight phase before re-grasping the bar (flight element)(minimum B).
- An »in-bar« element (minimum B).

If all the requirements were fulfilled in the Code of Points 1989 an exercise was worth 9.40 points. However, a gymnast could obtain the remaining 0.6 points by satisfying a scoring category called ROV which stands for risk, originality and virtuosity and could bring up to 0.2 points for each category thus making an exercise worth 10.0 points. Each category had to be evaluated separately, but in practice they were shown with the complexity of an exercise and together they formed a whole. For one part of an exercise it was possible to give two of three ROV factors (FIG, 1989).

Bonus points were a part of the score structure until the Code of Points 2001 came into force and gymnasts had to fulfill certain requirements to obtain points which could be awarded in this scoring category. With the new Code of Points in 2006 bonus points can be obtained only through connection of two elements of an appropriate value. Connection occurs when two flight elements or one flight and one on bar element are connected.

Additional criteria that increased element value or combined the two of them into one value part. There are several criteria in each Code of Points, however, only the selected ones had an impact on Aljaž's exercises:

- For the direct connection of flight elements, the succeeding flight element increases in value by 1 category. *Example:* Tkatchov (C part) followed by free flight Giant (B part) becomes C+C part *or* Kovacs (D part) followed by Deltchev (C part) becomes D+D part *or* Tkatchov (C part) 2x followed by Deltchev (C part) becomes C+D+D part (FIG, 1989, p. 218).
- For the direct connection of flight elements, the succeeding flight element increases in value by 1 category. *Example:* Tkatchov (C part) followed by free flight Giant (B part) becomes C+C part *or* Kovacs (E part) followed by Deltchev (C part) becomes E+D part *or* Tkatchov (C part) 2x followed by Deltchev (C part) becomes C+D+D part (FIG, 1993, p. 157).

Additional information about value parts (FIG, 2001, p. 114):

- The direct connection of two flight elements creates one single value part, as follows: C+C=D, C+D or D+C=E, C+E or E+C= super E.
- The direct connection of D+D, E+D, D+E, E+E or similar flight elements retain their independent values for the benefit of the gymnast.

During the time Aljaž competed in the senior category FIG changed the Code of Points seven times. The Code of Points changes every four years and sets new standards, which competitors have to match by learning new or upgrading existing elements and constructing new exercises.

Aljaž started competing in a senior category when the Code of Points 1989-1992 was in force. Up until the year 1996 a gymnast had to perform compulsory and optional exercises, thus performing two exercises for each apparatus. The sum of both exercises gave the final ranking of a gymnast. Compulsory exercises were the same for all gymnasts and they contained various elements, for which gymnasts spent a lot of time learning them. This paid off with a broad spectrum of knowledge which helped gymnasts to learn more difficult elements. After 1996 the compulsory exercises were cancelled.

Up until 2004 a gymnast exercise was evaluated from a starting value of 10 points downwards, provided an exercise fulfilled requirements set by the score structure. The score structure was divided into four sections. In each section a gymnast may have achieved a determined number of points, however, the points varied a lot through the Code of Points. By fulfilling requirements set by the score structure, a gymnast could achieve a maximum starting value. Great emphasis was placed on elegance of movement and reliability of performed elements. Gymnasts strived to perform their exercises in a flawless, elegant manner and with ease, because already the slightest mistake could mean a deduction, thus making a gymnast less competitive.

In 2006, the Code of Points and the entire gymnastics scoring system were completely overhauled. The change stemmed from the judging controversy at 2004 Olympics in Athens, Greece, which brought the reliability and objectivity of the scoring system into question, and arguments that execution had been sacrificed for difficulty in artistic gymnastics (Code of Points, 2014).

It started at 2004 Olympics in Athens when an American gymnast Paul Hamm won the gold medal in Men's all-around competition. However, his gold medal was put into doubt, by International Gymnastics Federation (FIG), when South Korean bronze medalist Yange Tae Young filed an official report, stating his start value was inaccurate in the all-around final event on parallel bars. Judges set Yange's start value to 9.9 instead of 10.0. This was enough to put Yange into the third place, since the difference between the first and the third place was only 0.049 points. If FIG would have ruled into Yanges' favor he would have won the gold and Hamm would have been second. FIG responded with suspension of three judges for the error and with the decision that the results will remain unchanged (Olympic Games scandals and controversies, 2014).

The Code of Points which was in force from 2000-2004 stayed active for another year, although the controversy about judging happened at the 2004 Olympics. The next Code of Points which was in force only three years from 2006-2008 no longer had a maximum starting value of 10 points, however, the final score was consisted out of two separate scores, the execution score and the difficulty score. The score for execution is evaluated by deduction from 10 points downwards. Judges deduct points for general, technical, artistic, executional and exercise composition errors. A difficulty score is consisted out of ten elements, including dismount. Summarized value of the ten elements, which values are shown in the value table, gives the difficulty score of an exercise. The sum of both scores gives the final score a gymnast will receive for his exercise (Code of Points, 2014).

The Codes of Points 2008 and 2012 that followed the new Code of Points which came into force in 2006 did not change a lot. Actually the only difference was in the value table and some new elements were added, which are given the name by a gymnast who first executed them.

METHODS

Searching, reviewing, analyzing and verifying the results and video material for each World Championship and Code of Points for individual era.

Exercises for each World Championship are broken down into individual elements and descriptions of elements. They are presented in accordance with the Code of Points which was in force for a particular four-year period, and in theoretical comparison, taking into account all changes and adjustments, with the 2013 Code of Points.

Input, processing and data design, such as the date of the competition, achieved rank, exercise content (EGR, CIN, D, V, CP), exercise value were made in Microsoft Excel 2010.

Legend of abbreviations: EGR-element group requirements, CIN-code identification number, D-difficulty, V-value, CP-connection points

The breakdown of exercises Aljaž performed at the World Championships

Despite best efforts, it was not possible to obtain all the exercises for each of the individual World Championships. Therefore, the analysis of certain exercises is made on the basis of other competitions that were close to the time of the World Championship, for which it was not possible to obtain any video material. Based on a discussion and joint work with, it was concluded that such an exercise was probably the same as the one performed at the World Championship.

Analysis of the following world championship exercises was not possible, because there was not an adequate video material:

- Exercise for the 1991 World Championship in Indianapolis, was analysed based on the exercise Aljaž performed at the National Championship in 1991 in Ljubljana, Slovenia.
- Exercise for the 1995 World Championship in Sabae, was analysed based on the exercise Aljaž performed at World Cup in 1994 in Zürich, Switzerland.
- Exercise for the 1999 World Championship in Tijanjin, was analysed based on the exercise Aljaž performed at World Cup in 2000 in Ljubljana, Slovenia.

Exercise for the 2001 World Championship in Ghent, was analysed based on the exercise Aljaž performed at World Cup in 2001 in Glasgow, United Kingdom.

Table 1
Bonus points through Codes of Points 1993-2013.

Code of Points		CP max	Total max points
1993	Each D = 0,1, each E = 0,2; CP (C,D,E); CD, DC, CE, EC, DD = 0,1; DE, EE, ED = 0,2	0,2	1
1997	Each D = 0,1, each E = 0,2, each SE = 0,3; CP (C,D,E); CD, DC, CE, EC, DD = 0,1; DE, EE, ED = 0,2; CP for two C flight elements; CC = 0,1		1,4
2001	Each D = 0,1, each E = 0,2, each SE = 0,3; CP (C,D,E); CD, DC, CE, EC, DD = 0,1; DE, EE, ED = 0,2		1,2
2006	On bar Flight D or E or F + D or E or F = 0,2 or vice versa Flight Flight D or E or F + C = 0,1 D or E or F + D or E or F = 0,2 or vice versa		Depending on how many connections a gymnast will make
2009	On bar Flight D or E or F + D or E or F = 0,2 or vice versa Flight Flight D or E or F + C = 0,1 D or E or F + D or E or F = 0,2 or vice versa		Depending on how many connections a gymnast will make
2013	On bar Flight D or E or F + D or E or F = 0,2 or vice versa Flight Flight C or D or E or F + C = 0,1 D or E or F + D or E or F = 0,2 or vice versa		Depending on how many connections a gymnast will make

Table 2
Score structure and value parts through Codes of Points 1989-2013.

Code of Points	1989	1993	1997	2001	2006	2009 & 2013
Max score	10.000	10.000	10.000	10.000	Note	Note
Exercise base value	4,0	2,4	2,4	2,8	10 elements	10 elements
Exercise execution	4,4	5,4	5,0	5,0	10.000	10.000
Special requirements (Exercise composition)	1,0	1,2	1,2	1,0	2,5	2,5
Connection / bonus points (ROV)	0,6	1,0	1,4	1,2	*	*
Value parts						
A	0,1	0,1	0,1	0,1	0,1	0,1
B	0,2	0,2	0,2	0,3	0,2	0,2
C	0,4	0,4	0,3	0,5	0,3	0,3
D	0,6	0,6	0,4	0,6	0,4	0,4
E		0,8	0,6	0,7	0,5	0,5
F (SE)			0,7	0,8	0,6	0,6
G						0,7
N of elements	9	10	10	10	10	10

* depending on the connection of elements

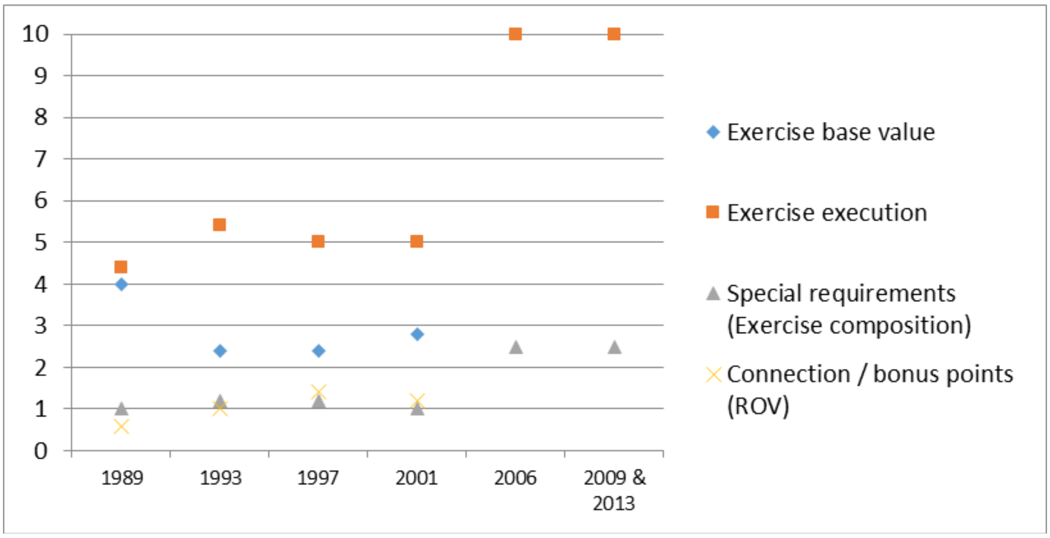

Figure 2. Score structure through Code of Points 1989-2013.

Table 3
Aljaž Pegan exercise content and results at World Championship.

Performed exercise at 1991 World Championship in Indianapolis and sections of score structure (Mešl Jože personal archive)

1991 Indianapolis, United States	Code of Points 1989				Code of Points 2013			
9.400/10.000								
63-70. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/1	A		0,2	III/7	A		0,1
Stalder strad.	IV/38	B		0,4	III/38	B		0,2
Giant swing bwd.	V/25	A			I/31	A		0,1
Tkatchev strad.	VI/11	C		0,6	II/15	C	0,1	0,3
Gienger	VI/67	D		0,8	II/69	C		0,3
At front swing 1/2 turn around left hand in mixt grip								
At front swing regrip to undergrip								
Endo strad.	IV/22	B		0,4	III/26	B		0,2
Giant swing fwd.	V/1	A			I/13	A		
Stoop circle rearward fwd. atleast 45°	IV/2	B		0,4	IV/2	B		0,2
El-grip giant swing	V/18	B		0,4	IV/14	B		0,2
El-grip back uprise and hop ½ t. to ovgr.	V/22	B		0,4	IV/20	B		0,2
Giant swing bwd.	V/25	A			I/31	A		
Giant swing bwd.	V/25	A			I/31	A		
Triple salto bwd. t.	VII/52	D		0,8	V/47	E		0,5
Exercise base value (max 4,4)				4,4	EGRF I-V (2,5 max)			2,5
Exercise execution (max 4)				4	Exercise execution			10
Exercise composition (max 1)				1	CP			0,1
Bonus ROV (max 0,6)				0,6				
Start value				10				14,9

Performed exercise at 1992 World Championship in Paris and sections of score structure (Mešl Jože personal archive)

1992 Paris, France	Code of Points 1989				Code of Points 2013			
9.400/10.000								
21. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/1	A			III/7	A		0,1
Stalder strad.	IV/38	B		0,4	III/38	B		0,2
Giant swing bwd.	V/25	A			I/31	A		
Tkatchev strad.	VI/11	C		0,6	II/15	C		0,3
Tkatchev strad.	VI/11	D		0,8	II/15	C	0,1	
Gienger	VI/67	D		0,8	II/69	C		0,3
At front swing 1/2 turn around left hand in mixt grip								
At front swing regrip to undergrip								
Endo strad.	IV/22	B		0,4	III/26	B		0,2
Giant swing fwd.	V/1	A			I/13	A		
Stoop circle rearward fwd. atleast 45°	IV/2	B		0,4	IV/2	B		0,2
El-grip giant swing	V/18	B		0,4	IV/14	B		0,2
El-grip back uprise and hop ½ t. to ovgr.	V/22	B		0,4	IV/20	B		0,2
One arm giant swing bwd. (360°)	V/30	B		0,4	I/32	B		0,2
Giant swing bwd.	V/25	A			I/31	A		
Giant swing bwd.	V/25	A			I/31	A		
Triple salto bwd. t.	VII/52	D		0,8	V/47	E		0,5
Exercise base value (max 4,4)				4,4	EGRF I-V (2,5 max)			2,5
Exercise execution (max 4)				4	Exercise execution			10
Exercise composition (max 1)				1	CP			0,1
Bonus ROV (max 0,6)				0,6				
Start value				10				15

Performed exercise at 1993 World Championship in Birmingham and sections of score structure (Gymn, 2004)

1993 Birmingham, United Kingdom 9.150/ 10.000	Code of Points 1993				Code of Points 2013			
12. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/1	A			III/7	A		0,1
Endo strad. with 1/2 t. thr. hdst.	IV/28	C		0,4	III/32	B		0,2
Giant swing bwd. with 1/2 turn	V/57	B		0,2	I/37	A		
Giant swing fwd.	V/1	A			I/13	A		
Giant swing fwd.	V/1	A			I/13	A		
Pegan	VI/65	E		0,8	II/53	E		0,5
Giant swing bwd.	V/31	A			I/31	A		
Tkatchev strad.	VI/13	C		0,4	II/15	C		0,3
Tkatchev strad.	VI/13	D	0,1	0,6	II/15	C	0,1	
Gienger	VI/83	D		0,6	II/69	C		0,3
At front swing regrip to undergrip								
Kip or drop kip to hdst. regrip to undergrip	I/6	A			III/1	A		
Giant swing fwd.	V/1	A			I/13	A		
Stoop circle rearward fwd. atleast 45°	IV/2	B		0,2	IV/2	B		0,2
El-grip giant swing	V/22	B		0,2	IV/14	B		0,2
El-grip back uprise and hop ½ t. to ovgr.	V/27	B			IV/20	B		0,2
Giant swing fwd.	V/1	A			I/13	A		
Zou Li Min	V/19	D		0,6	I/27	C		0,3
Endo strad. with 1/2 turn	V/27	B			III/32	B		
Giant swing bwd.	V/31	A			I/31	A		
Giant swing bwd.	V/31	A			I/31	A		
Triple salto bwd. t.	VII/64	D		0,6	V/47	E		0,5
Exercise base value (max 2,4)				2,4	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5,4)				5,4	Exercise execution			10
Special requirements (max 1,2)				1,2	CP			0,1
Bonus points (max 1)				1				
Start value				10				15,4

Performed exercise at 1994 World Championship in Brisbane and sections of score structure (Gymnastics Results, 1994)

1994 Brisbane, Australia 9.275/ 10.000	Code of Points 1993				Code of Points 2013			
6. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/1	A			III/7	A		0,1
Endo piked with 1/2 t. thr. hdst.	IV/24	D		0,6	III/32	B		0,2
Giant swing bwd. with 1/2 turn	V/57	B		0,2	I/37	A		0,1
Giant swing fwd.	V/1	A			I/13	A		
Giant swing fwd.	V/1	A			I/13	A		
Pegan	VI/65	E		0,8	II/53	E		0,5
Giant swing bwd.	V/31	A			I/31	A		
Tkatchev strad.	VI/13	C		0,4	II/15	C		0,3
Tkatchev strad.	VI/13	D	0,1	0,6	II/15	C	0,1	
Gienger	VI/83	D		0,6	II/69	C		0,3
Endo strad. with 1/2 t. thr. hdst.	IV/28	C		0,4	III/32	B		
Giant swing bwd. with 1/2 turn	V/57	B			I/37	A		
Zou Li Min	V/19	D	0,1	0,6	I/27	C		0,3
Endo strad. regrip to el-grip	IV/34	D		0,6	III/26	B		0,2
El-grip back uprise and hop ½ t. to ovgr.	V/27	B			IV/20	B		0,2
Giant swing bwd.	V/31	A			I/31	A		
Giant swing bwd.	V/31	A			I/31	A		
Triple salto bwd. t.	VII/64	D		0,6	V/47	E		0,5
Exercise base value (max 2,4)				2,4	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5,4)				5,4	Exercise execution			10
Special requirements (max 1,2)				1,2	CP			0,1
Bonus points (max 1)				1				
Start value				10				15,3

Performed exercise at 1995 World Championship in Sabae and sections of score structure (Gymnastics Results, 1995)

1995 Sabae, Japan	Code of Points 1993				Code of Points 2013			
9.700/10.000								
90. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/1	A			III/7	A		0,1
Endo piked with 1/2 t. thr. hdst.	IV/24	D		0,6	III/32	B		0,2
Giant swing bwd. with 1/2 turn	V/57	B		0,2	I/37	A		0,1
Giant swing fwd.	V/1	A			I/13	A		
Giant swing fwd.	V/1	A			I/13	A		
Pegan	VI/65	E		0,8	II/53	E		0,5
Giant swing bwd.	V/31	A			I/31	A		
Tkatchev strad.	VI/13	C		0,4	II/15	C		0,3
Tkatchev strad.	VI/13	D	0,1	0,6	II/15	C	0,1	
Gienger	VI/83	D		0,6	II/69	C		0,3
Endo strad. with 1/2 t. thr. hdst.	IV/28	C		0,4	III/32	B		
Giant swing bwd. with 1/2 turn	V/57	B			I/37	A		
Zou Li Min	V/19	D	0,1	0,6	I/27	C		0,3
Endo strad. regrip to el-grip	IV/34	D		0,6	III/26	B		0,2
El-grip back uprise and hop ½ t. to ovgr.	V/27	B			IV/20	B		0,2
Giant swing bwd.	V/31	A			I/31	A		
Giant swing bwd.	V/31	A			I/31	A		
Triple salto bwd. t.	VII/64	D		0,6	V/47	E		0,5
Exercise base value (max 2,4)				2,4	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5,4)				5,4	Exercise execution			10
Special requirements (max 1,2)				1,2	CP			0,1
Bonus points (max 1)				1				
Start value				10				15,3

Performed exercise at 1996 World Championship in San Juan and sections of score structure (Gymnastics Results, 1996)

1996 San Juan, Portorico	Code of Points 1993				Code of Points 2013			
9.750/10.000								
4. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/1	A			III/7	A		0,1
Endo piked with 1/2 t. thr. hdst.	IV/24	D		0,6	III/32	B		0,2
Giant swing bwd. with 1/2 turn	V/57	B		0,2	I/37	A		0,1
Giant swing fwd.	V/1	A			I/13	A		
Giant swing fwd.	V/1	A			I/13	A		
Pegan	VI/65	E		0,8	II/53	E		0,5
Giant swing bwd.	V/31	A			I/31	A		
Tkatchev strad.	VI/13	C		0,4	II/15	C		0,3
Tkatchev strad.	VI/13	D	0,1	0,6	II/15	C	0,1	
Gienger	VI/83	D		0,6	II/69	C		0,3
Endo strad. with 1/2 t. thr. hdst.	IV/28	C		0,4	III/32	B		
Giant swing bwd. with 1/2 turn	V/57	B			I/37	A		
Giant swing fwd. with one arm in ungr. (360°)	V/2	B			I/26	B		0,2
Zou Li Min	V/19	D	0,1	0,6	I/27	C		0,3
Endo strad. regrip to el-grip	IV/34	D		0,6	III/26	B		
El-grip back uprise and hop ½ t. to ovgr.	V/27	B			IV/20	B		0,2
Giant swing bwd.	V/31	A			I/31	A		
Giant swing bwd.	V/31	A			I/31	A		
Triple salto bwd. t.	VII/64	D		0,6	V/47	E		0,5
Exercise base value (max 2,4)				2,4	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5,4)				5,4	Exercise execution			10
Special requirements (max 1,2)				1,2	CP			0,1
Bonus points (max 1)				1				
Start value				10				15,3

Performed exercise at 1999 World Championship in Tianjin and sections of score structure (Gymnastics Results, 1999)

1999 Tianjin, China	Code of Points 1997				Code of Points 2013			
9.587/10.000								
13. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/1	A			III/7	A		0,1
Endo piked with 1/2 t. thr. hdst.	III/64	D	0,1	0,4	III/32	B		0,2
Stalder with hop 1/1 t. through hdst.	III/29	D	0,1	0,4	III/39	C		0,3
Stalder with hop 1/1 t. through hdst.	III/29	D		0,4	III/39	C		
Giant swing bwd. with 1/2 turn	IV/22	B			I/37	A		
Giant swing fwd.	IV/1	A			I/13	A		
Giant swing fwd.	IV/1	A			I/13	A		
Pegan	VI/45	E		0,6	II/53	E		0,5
Giant swing bwd.	IV/21	A			I/31	A		
Tkatchev strad.	VI/13	C	0,1	0,3	II/15	C	0,1	0,3
Gienger	VI/63	C		0,3	II/69	C		0,3
Endo strad. with 1/2 t. thr. hdst.	III/53	C		0,3	III/32	B		
Giant swing bwd. with 1/2 turn	IV/22	B			I/37	A		
Zou Li Min	V/19	D	0,2	0,4	I/27	C		0,3
Endo strad. with 1/1 t. thr. hdst. in el-grip	III/65	E		0,6	III/34	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	V/7	B			IV/20	B		0,2
Giant swing bwd.	IV/21	A			I/31	A		
Giant swing bwd.	IV/21	A			I/31	A		
Triple salto bwd. t.	VII/54	D		0,4	V/47	E		0,5
Exercise base value (max 2,4)				2,4	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5)				5	Exercise execution			10
Special requirements (max 1,2)				1,2	CP			0,1
Bonus points (max 1,4)				1,4				
Start value				10				15,7

Performed exercise at 2001 World Championship in Ghent and sections of score structure (Gymnastics Results, 2001)

2001 Ghent, Belgium	Code of Points 2000				Code of Points 2013			
8.350/10.000								
70. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/6	A		0,1	III/7	A		0,1
Endo strad. with 1/2 t. thr. hdst.	III/26	B		0,3	III/32	B		0,2
Giant swing bwd. with 1/2 turn	I/31	A		0,1	I/37	A		0,1
Giant swing fwd.	I/11	A			I/13	A		
Giant swing fwd.	I/11	A			I/13	A		
Pegan	II/45	E		0,7	II/53	E		0,5
Giant swing bwd.	I/26	A			I/31	A		
Tkatchev piked	II/14	D	E	0,7	II/15	C		0,3
Tkatchev strad.	II/13	C			II/15	C	0,1	
Gienger	II/58	C	D	0,6	II/69	C		0,3
Endo strad. with 1/2 t. thr. hdst.	III/26	B			III/32	B		
Giant swing bwd. with 1/2 turn	I/31	A			I/37	A		
Zou Li Min	I/28	C		0,5	I/27	C		0,3
Endo strad. with 1/1 t. thr. hdst. in el-grip	III/40	E		0,7	III/34	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	IV/17	B		0,3	IV/20	B		0,2
Giant swing bwd.	I/26	A			I/31	A		
Giant swing bwd.	I/26	A			I/31	A		
Triple salto bwd. t.	V/40	E		0,7	V/47	E		0,5
Exercise base value (max 2,8)				2,8	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5)				5	Exercise execution			10
Special requirements (max 1)				1	CP			0,1
Bonus points (max 1,2)				1,2				
Start value				10				15,4

Performed exercise at 2002 World Championship in Debrecen and sections of score structure (Gymnastics Results, 2002)

2002 Debrecen, Hungary	Code of Points 2000				Code of Points 2013			
9.700/10.000								
2. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/6	A		0,1	III/7	A		0,1
Endo strad. with 1/2 t. thr. hdst.	III/26	B		0,3	III/32	B		0,2
Giant swing bwd. with 1/2 turn	I/31	A			I/37	A		0,1
Giant swing fwd.	I/11	A			I/13	A		
Giant swing fwd.	I/11	A			I/13	A		
Pegan	II/45	E		0,7	II/53	E		0,5
Giant swing bwd.	I/26	A			I/31	A		
Tkatchev piked	II/14	D	E	0,7	II/15	C		0,3
Tkatchev strad.	II/13	C			II/15	C	0,1	0,3
Gienger	II/58	C	D	0,6	II/69	C		
Endo piked with 1/2 t. thr. hdst.	III/26	B			III/32	B		
Giant swing bwd. with 1/2 turn	I/31	A			I/37	A		
Endo with 1/1 t. thr. hdst. in el-grip	III/40	E		0,7	III/34	D		0,4
El-grip back uprise and hop to undr.	IV/17	B		0,3	IV/20	B		0,2
Giant swing fwd. with 1/1 turn in double elgrip	I/23	C		0,5	I/15	C		0,3
El-grip back uprise and hop to undr.	IV/17	B			IV/20	B		
Giant swing fwd.	I/11	A			I/13	A		
Giant swing fwd. with 1/1 turn in mixt grip	I/12	B		0,3	I/14	B		
Back uprise to handstand with 1/2 turn	I/6	A			I/7	A		
Giant swing bwd.	I/26	A			I/31	A		
Giant swing bwd.	I/26	A			I/31	A		
Triple salto bwd. t.	V/40	E		0,7	V/47	E		0,5
Exercise base value (max 2,8)				2,8	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5)				5	Exercise execution			10
Special requirements (max 1)				1	CP			0,1
Bonus points (max 1,2)				1,2				
Start value				10				15,4

Performed exercise at 2003 World Championship in Anaheim and sections of score structure (Gymnastics Results, 2003)

2003 Anaheim, United States	Code of Points 2000				Code of Points 2013			
9.500/10.000								
24. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/6	A		0,1	III/7	A		0,1
Endo strad. with 1/2 t. thr. hdst.	III/26	B		0,3	III/32	B		0,2
Giant swing bwd. with 1/2 turn	I/31	A			I/37	A		0,1
Giant swing fwd.	I/11	A			I/13	A		
Giant swing fwd.	I/11	A			I/13	A		
Pegan	II/45	E		0,7	II/53	E		0,5
Giant swing bwd.	I/26	A			I/31	A		
Tkatchev piked	II/14	D	E	0,7	II/15	C		0,3
Tkatchev strad.	II/13	C			II/15	C	0,1	
Gienger	II/58	C	D	0,6	II/69	C		0,3
Endo piked with 1/2 t. thr. hdst.	III/26	B			III/32	B		
Giant swing bwd. with 1/2 turn	I/31	A			I/37	A		
Endo piked with 1/1 t. thr. hdst. in el-grip	III/40	E		0,7	III/34	D		0,4
El-grip back uprise and hop to undr.	IV/17	B		0,3	IV/20	B		0,2
Giant swing fwd. with 1/1 turn in double elgrip	I/23	C		0,5	I/15	C		0,3
El-grip back uprise and hop to undr.	IV/17	B			IV/20	B		
Giant swing fwd.	I/11	A			I/13	A		
Giant swing fwd. with 1/1 turn in mixt grip	I/12	B		0,3	I/14	B		
Back uprise to handstand with 1/2 turn	I/6	A			I/7	A		
Giant swing bwd.	I/26	A			I/31	A		
Giant swing bwd.	I/26	A			I/31	A		
Triple salto bwd. t.	V/40	E		0,7	V/47	E		0,5
Exercise base value (max 2,8)				2,8	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5)				5	Exercise execution			10
Special requirements (max 1)				1	CP			0,1
Bonus points (max 1,2)				1,2				
Start value				10				15,4

Performed exercise at 2005 World Championship in Melbourne and sections of score structure (Gymnastics Results, 2005)

2005 Melbourne, Australia 9.662/10.000	Code of Points 2000				Code of Points 2013			
1. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From overgrip free hip circle through handstand	III/6	A			III/7	A		0,1
Endo piked with 1/1 t. thr. hdst. in mixt grip	III/27	C		0,5	III/33	C		0,3
Back uprise to handstand with 1/2 turn	I/6	A			I/7	A		
Giant swing bwd. with 1/2 turn	I/31	A			I/37	A		
Giant swing fwd.	I/11	A			I/13	A		
Giant swing fwd.	I/11	A			I/13	A		
Pegan	II/45	E		0,7	II/53	E		0,5
Giant swing bwd.	I/26	A			I/31	A		
Tkatchev piked	II/14	D	E	0,7	II/15	C		0,3
Tkatchev strad.	II/13	C			II/15	C	0,1	
Gienger	II/58	C	D	0,6	II/69	C		0,3
Endo strad. with 1/1 t. thr. hdst. in el-grip	III/28	C		0,5	III/34	D		0,4
El-grip back uprise and hop to undr.	IV/17	B		0,3	IV/20	B		0,2
Giant swing bwd.	I/26	A			I/31	A		
Zou Li Min	I/28	C		0,5	I/27	C		0,3
Giant swing fwd.	I/11	A			I/13	A		
Endo piked with 1/1 t. thr. hdst. in el-grip	III/40	E		0,7	III/34	D		
El-grip back uprise and hop to undr.	IV/17	B			IV/20	B		
Giant swing fwd. with 1/1 turn in double elgrip	I/12	B		0,3	I/15	C		0,3
El-grip back uprise and hop ½ t. to ovgr.	IV/17	B			IV/20	B		
Giant swing bwd.	I/26	A			I/31	A		
Giant swing bwd.	I/26	A			I/31	A		
Triple salto bwd. t.	V/40	E		0,7	V/47	E		0,5
Exercise base value (max 2,8)				2,8	EGRF I-V (2,5 max)			2,5
Exercise execution (max 5)				5	Exercise execution			10
Special requirements (max 1)				1	CP			0,1
Bonus points (max 1,2)				1,2				
Start value				10				15,8

Performed exercise at 2006 World Championship in Aarhus and sections of score structure (Gymnastics Results, 2006)

2006 Aarhus, Denmark 15.900/16.500	Code of Points 2006				Code of Points 2013			
2. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From mixt grip free hip circle through handstand	III/7	A			III/7	A		
Endo strad. with 1/1 t. thr. hdst. in mixt grip	III/33	C		0,3	III/33	C		0,3
Back uprise to handstand with 1/2 turn	I/7	A			I/7	A		
Giant swing bwd. with 1/2 turn	I/37	A			I/37	A		
Giant swing fwd.	I/13	A			I/13	A		
Giant swing fwd.	I/13	A			I/13	A		
Pegan	II/53	E	0,2	0,5	II/53	E	0,1	0,5
Rybalko with 3/2 t. to double el-grip	I/64	D		0,4	I/64	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	IV/20	B		0,2	IV/20	B		0,2
Stalder strad. with hop 3/2 turn through hdst. in el-grip	III/41	D		0,4	III/41	D		0,4
Back uprise to handstand with 1/2 turn	I/7	A			I/7	A		
Giant swing fwd.	I/13	A			I/13	A		
Stalder strad. with hop 3/2 turn through hdst. in el-grip	III/41	E		0,5	III/41	E		0,5
El-grip back uprise and hop to undr.	IV/20	B			IV/20	B		
Giant swing fwd.	I/13	A			I/13	A		
Zou Li Min	I/27	C		0,3	I/27	C		0,3
Endo strad. with 1/1 t. thr. hdst. in el-grip	III/34	D		0,4	III/34	D		0,4
El-grip back uprise and hop to undr.	IV/20	B			IV/20	B		
Giant swing fwd. with 1/1 turn in double elgrip	I/15	C		0,3	I/15	C		0,3
El-grip back uprise and hop ½ t. to ovgr.	IV/20	B			IV/20	B		
Giant swing bwd.	I/31	A			I/31	A		
Giant swing bwd.	I/31	A			I/31	A		
Triple salto bwd. t.	V/47	E		0,5	V/47	E		0,5
EGRF I-V (2,5 max)				2,5				2,5
Exercise execution				10				10
CP				0,2				0,1
Start value				16,5				16,4

Performed exercise at 2007 World Championship in Stuttgart and sections of score structure (Gymnastics Results, 2007)

2007 Stuttgart, Germany 15.825/16.800	Code of Points 2006				Code of Points 2013			
2. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From mixt grip free hip circle through handstand	III/7	A			III/7	A		
Endo strad. with 1/1 t. thr. hdst. in el-grip	III/34	D		0,4	III/34	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	IV/20	B			IV/20	B		
Giant swing bwd. with 1/2 turn	I/37	A			I/37	A		
Giant swing fwd.	I/13	A			I/13	A		
Giant swing fwd.	I/13	A			I/13	A		
Pegan	II/53	E	0,2	0,5	II/53	E	0,1	0,5
Rybalko with 3/2 t. to double el-grip	I/64	D		0,4	I/64	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	IV/20	B			IV/20	B		
Stalder strad. with hop 3/2 turn through hdst. in el-grip	III/41	E		0,5	III/41	E		0,5
El-grip back uprise and hop to undr.	IV/20	B			IV/20	B		
Giant swing fwd.	I/13	A			I/13	A		
Stoop in shoot and 1/2 t. thr. hdst. in ovgr.	IV/4	D		0,4	IV/4	D		0,4
Giant swing bwd.	I/31	A			I/31	A		
Stalder with hop 1/1 t. thr. hdst. in el-grip (change de rotation direction)	III/40	D		0,4	III/40	D		0,4
El-grip back uprise and hop to undr.	IV/20	B			IV/20	B		
Giant swing fwd.	I/13	A			I/13	A		
Zou Li Min	I/27	C		0,3	I/27	C		0,3
Weiler with 1/1 turn to double el-grip	III/4	D		0,4	III/4	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	IV/20	B			IV/20	B		
Quast with 1/1 turn	I/45	C		0,3	I/45	C		0,3
Giant swing bwd.	I/31	A			I/31	A		
Giant swing bwd.	I/31	A			I/31	A		
Triple salto bwd. t.	V/47	E		0,5	V/47	E		0,5
EGRF I-V (2,5 max)				2,5				2,5
Exercise execution				10				10
CP				0,2				0,1
Start value				16,8				16,7

Performed exercise at 2009 World Championship in London and sections of score structure (Gymnastics Results, 2009)

2009 London, United Kingdom 15.500/17.000	Code of Points 2006				Code of Points 2013			
5. place	EGR/CIN	D	CP	V	EGR/CIN	D	CP	V
From mixt grip free hip circle through handstand	III/7	A			III/7	A		
Endo strad. with 1/1 t. thr. hdst. in el-grip	III/34	D		0,4	III/34	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	IV/20	B			IV/20	B		
Giant swing bwd. with 1/2 turn	I/37	A			I/37	A		
Giant swing fwd.	I/13	A			I/13	A		
Giant swing fwd.	I/13	A			I/13	A		
Pegan	II/53	E	0,2	0,5	II/53	E	0,1	0,5
Rybalko with 3/2 t. to double el-grip	I/64	D		0,4	I/64	D		0,4
El-grip back uprise and hop ½ t. to ovgr.	IV/20	B			IV/20	B		
Giant swing bwd.	I/31	A			I/31	A		
Stalder strad. with hop 3/2 turn through hdst. in el-grip	III/41	E		0,5	III/41	E		0,5
Back uprise to handstand and hop to undr.	I/1	A			I/1	A		
Giant swing fwd.	I/13	A			I/13	A		
Stoop in shoot and 1/2 t. thr. hdst. in ovgr.	IV/4	D	0,2	0,4	IV/4	D	0,1	0,4
Možnik strad. to mixt grip	II/17	D		0,4	II/17	D		0,4
Back uprise to handstand and hop to undr.	I/1	A			I/1	A		
Giant swing fwd. with 1/2 t. thr. hdst.	I/19	A			I/19	A		
Stalder with hop 1/1 t. thr. hdst. in el-grip (change de rotation direction)	III/40	D		0,4	III/40	D		0,4
El-grip back uprise and hop to undr.	IV/20	B			IV/20	B		
Giant swing fwd.	I/13	A			I/13	A		
Zou Li Min	I/27	C		0,3	I/27	C		0,3
Giant swing fwd. with 1/2 t. thr. hdst.	I/19	A			I/19	A		
Quast with 1/1 turn	I/45	C		0,3	I/45	C		0,3
Giant swing bwd.	I/31	A			I/31	A		
Giant swing bwd.	I/31	A			I/31	A		
Triple salto bwd. t.	V/47	E		0,5	V/47	E		0,5
EGRF I-V (2,5 max)				2,5				2,5
Exercise execution				10				10
CP				0,4				0,2
Start value				17				16,8

DISCUSSION

Every Code of Points that came into force had set new criteria to which gymnasts had to adapt. Aljaž managed to do that because of his wide spectrum of base knowledge. The base was built through years of training and a great number of repetitions of various elements he had to execute in compulsory exercises. Consequently, he could upgrade elements he had already known with an extra rotation or with a mixed or el-grip grips, thus executing elements and entire exercises with higher value. It can be seen through exercises how he upgraded his elements e.g. Endo was first executed with ½ turn and later with 1/1 turn, a similar connection is seen with Stalder. With this kind of changes and his elegant execution, Aljaž managed to remain one of the top competitors in the world men's artistic gymnastics.

When comparing exercises with difficulty values, with the Code of Points in 2013, they suffer since it became forbidden to count the same element (same Code Identification Number) in the exercise more than once. Therefore, some elements were excluded when making a theoretical comparison. Code identification number is an important factor in this rule because many forms of the same element e.g. Endo stradled and piked, became combined under the same code identification number. Further examples are elements that end in mixt or over - grip. All in all, when making a theoretical comparison to the Code of Points 2013, an exercise loses some points.

Another aspect that changed in Aljaž's exercises was their length which was primarily due to giant swings forward and backwards. Those giant swings were designed as a preparation for an element of high value. In spite of the length of an exercise only ten elements were taken into account when calculating the value of an exercise.

When composing an exercise a gymnast must consider which elements and in what order the elements will be connected. In the Codes of Points 1989-2001 a starting value of an exercise was limited to 10 points. Each exercise was composed from four sections. One of them - base value dictated how many points a gymnast may achieve as a combined value of ten elements. If the value of elements exceeded an upper limit of points dedicated to the section a gymnast achieved a maximum number of points and the expedience of points was not relevant. According to the Code of Points 2006 a gymnast exercise is no longer limited with an upper limit, but is rather open and solely a consequence of the sum of the elements in the exercise and the connections between them.

Figure 3. Score structure through Code of Points 1989-2001.

Figure 3 shows four sections of the score structure and how points dedicated for each section varied between these sections through the Code of Points 1989-2001.

Each element described in the Code of Points has a predetermined value. A set of discrete values that the element can obtain is characteristic of each individual Code of Points and thus the values vary through the years. After the 2006 values were stabilized, however before that, values sway in both directions, sometimes unreasonably so.

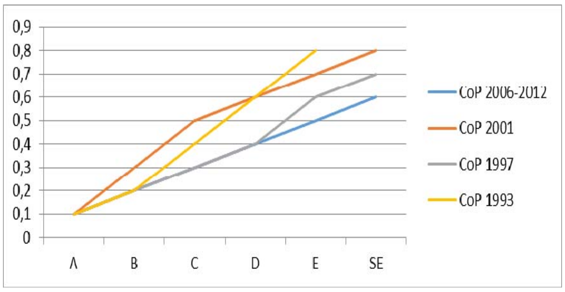

Figure 4. Value of value parts through Code of Points 1993-2006.

Figure 4 shows values of value parts through the period of the Code of Points 1993 to 2006-2012. The curve of the Code of Points 2006-2012 is overlapping with the curve of the Code of Points 1997 at value parts C and D, and curve of the Code of Points 1993 overlap both pervious Codes of Points at value part B. In all Codes of Points the value part A has the value of 0.1 point.

On the basis of an exercise start value and the score achieved, a percentage was calculated. The percentage shows to what extent Aljaž had achieved an exercise start value. Aljaž was one of the most elegant gymnasts on the horizontal bar so there is little surprise that the percentages are high (above 84%). Furthermore, the chart also shows that he executed exercises with great reliability.

Figure 5. Starting values and percentage of achieved score for World Championships 1991-2009

Figure 5 shows exercise start values and percentage which was calculated on the basis of exercise start value and achieved score.

The following graph shows a received score and an achieved place at each World Championship. Achieved places and received scores are also displayed in the charts for each World Championship.

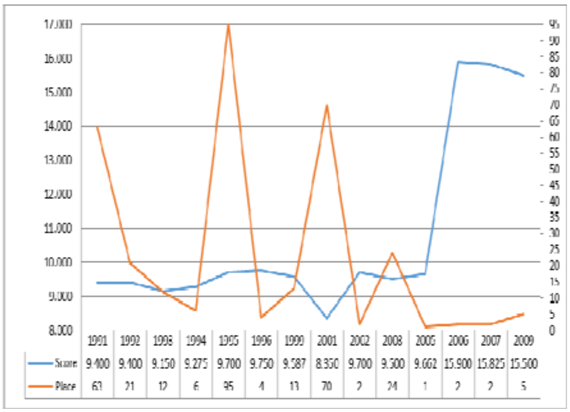

Figure 6. Achieved scores at World Championships 1991-2009 and ranks

Figure 6 shows final scores Aljaž received at each World Championship. The curve jumps after the year of 2005 because after that the new Code of Points was in force.

The next graph shows how small the differences are in gymnastics. The comparison of a winner and Aljaž shows how little difference is between them. It is safe to assume that reliability and elegance of execution was one of the key factors for winning medals until the Code of Points 2006. After which a gymnast who could execute harder exercises had an enormous advantage compared to other gymnasts. An additional important factor in the new Code of Points is the starting value of an exercise and a difference between the starting value and final score shows which gymnast had executed his exercise with a minimum number of errors. However, this factor is not presented in the graph.

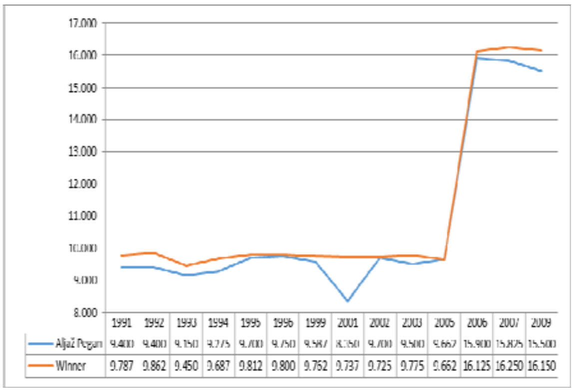

Figure 7. Comparison of Aljažs' score and the winners at World Championships 1991-2009

Figure 7 shows final scores of Aljaž Pegan and the winner at each world championship. The curve jumps after the year of 2005 because after that the new Code of Points was in force.

The next graph shows how Aljažs' difficulty value of his exercises changed through the years. Difficulty values of exercises are taken from exercises theoretical comparison to the Code of Points 2013.

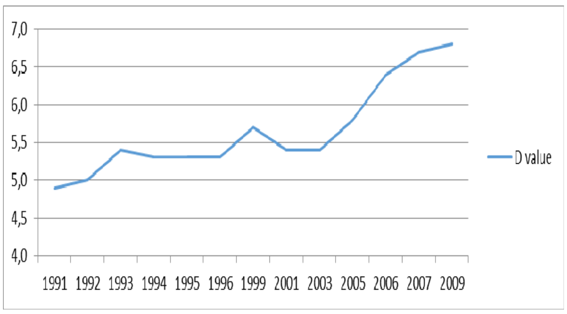

Figure 8. Development of an exercises D value compared to the Code of Points 2013.

Figure 8 shows how his difficulty value is consistent when the closed Code of Points was in force and with the new open Code of Points after 2006 his difficulty value increases in a shape of parabola, which is a typical curve of progress.

The following chart shows the percentage of Aljaž final ranking in the 144 international competitions (FIG, UEG) between 1991 - 2013. The percentages up to the 8th place are shown separately, since this is the limit for gymnasts to compete in the final on each apparatus. For a better overview places between 9 and 95 are put together.

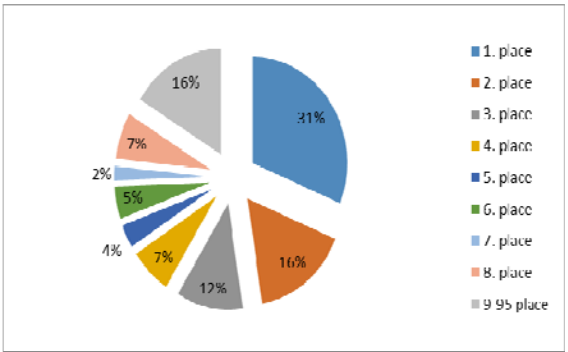

Figure 9. Percentage of achieved ranks at official FIG and UEG international competitions

CONCLUSION

The purpose of this case report was the presentation of exercises Aljaž Pegan had performed at the fourteen World Championships he had attended in his career. This case report also includes the breakdowns of seven Codes of Points for the horizontal bar through 1989-2013.

Through breakdowns of each exercise the development of exercises in relation to the changes in the Codes of Points can be seen. At the beginning exercises had more flight elements which made the exercise more attractive. With the development of the Code of Points and its focus on high value elements Aljaž had to upgrade his exercises with extra turns and el-grips or atypical grips. Due to these changes he managed to stay in the world summit through his entire career.

An overall review of Aljaž's 33 year long career shows that he competed in a senior category for more than 22 years. He performed at over a hundred international competitions, most of them were World Cups, and in many he ranked among the top three. Though he took part in various competitions including World Championships, World Cups, European Championships, Mediterranean Games, he never got an opportunity to perform at the Olympic Games. His greatest success is becoming the world champion in 2005, in Melbourne, Australia.

When collecting data from several years ago there was a problem collecting accurate data and the main reason is that no one is keeping reference. Our opinion and recommendation is that clubs and coaches make documentation for each individual gymnast, such as exercises, videos of exercises, mark important dates for gymnast career or execution of an element for the first time. Also save any periodization plan and training plans. Mark any exchange cooperation with foreign coaches and training under different conditions. Such documentation is necessary to show gymnast results were planned and to make a collection of data which is necessary for writing case reports like this one.

Authors of similar research should pay attention of collecting accurate data and make an effort of talking with anyone who might shed a light on a subject they are researching.

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AGE TRENDS IN ARTISTIC GYMNASTIC ACROSS WORLD CHAMPIONSHIPS AND THE OLYMPIC GAMES FROM 2003 TO 2016

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Original article

Abstract

The aim of research was to analysis development and age structure of male and female participants at the Olympic Games (OG) and World Championships (WC) from 2003 until 2016. The total number of analyzed WC participants in men's artistic gymnastics (MAG) was 2678 and the women's artistic gymnastics (WAG) was 1981; while at the OG in MAG 391 and in WAG 389. In the last 15 years, there has been identified linear and second-order polynomial-regression increase in the age structure of participants in MAG and WAG in the largest world competitions. In analyzed period of time, MAG and WAG age of gymnasts increased. The male gymnasts from 2003 to 2016 are on average older for 2.3 years and female gymnasts for 3.3 years. In the upcoming period, we do expect (with apparatus specialization) that age will rise.

Keywords*: artistic gymnastics, Code of Points, development, men, women.*

INTRODUCTION

Chronological age refers to the number of years and days elapsed since birth. Success in gymnastics is the result of many years of extensive planning and preparation by coaches, clubs, parents and other supporting partners. Long term development applies to all levels of participants and in all gymnastics disciplines. Scientific research (Drabik, 1996; Rost & Schon, 1997, Hofmann, 1999; Bompa, 1999, Arkaev & Suchilin, 2004; Balyi et al., 2005; Malina, 2010; Fink & Hofmann, 2015; Fink, Hofmann, & Ortiz Lopez, 2015) has concluded that it takes a minimum of ten years, 10,000 hours of deliberate training for a talented athlete to reach elite levels. This translates into an average of more than 3 hours of training daily for 10 years. There are no shortcuts; athlete development is a long term process.

Artistic Gymnastics in the 1950s and 1960s, the senior competition was dominated by athletes in their mid-to-late twenties. At the time, the “Code of Points” aimed more on artistry and was largely inspired by ballet. As a result, more seasoned gymnasts found success in the sport by bringing elegance to their routines. Up until 1981 the minimum age for participating in senior competitions was 14 years of age. In 1981, gymnasts were required to turn at least 15 years of age in the calendar year to compete in senior-level events. Since 1997, the Fédération Internatio-nale de Gymnastique, the gymnasts had to be at least 16 years old or to be turning 16 within the calendar year in order to take part in the competition as seniors. The age limit for participation at a world championship has been moved up. Today, the limit sits at 18 for MAG and 16 for the WAG (Sands et al., 2012; Grossfeld, 2014; FIG Technical Regulations 2017, Art. 5.2. Pg. 37).

However, the age limitations were introduced to gymnastics for: physiological reasons, protecting children from harmful exposure, time training, early growth, growth of body segments, pubertal growth and maturation, sex characteristics, menarche, nutritional status, weight-for-height, gymnastics training environment, familial factors. There is also the concern that imposed training limits could lead to more injuries (Anderson, 1997; Paul, 2010, Sands et al., 2012).

Research on age in timeline from 1964 until 1980 were conducted by Rozin & Čeburaev (1981) and showed age of top male gymnasts at the Olympic Games [OG1964, (M=25.6, SD=2.9); OG1968, (M=24.2, SD 3.4); OG1972, (M=24.6, SD=2.8); OG1976 (M=23.3, SD=4.0); OG1980, (M=23.2, SD=3.1)]. Minimum age for MAG participants was 13.0 years at the WC1987 and rose to 16.0 years at the 1997 WC. The age of men have since increased: 16.5 (WC1987), 17.4 (WC1997), 18.0 (OG2000), and 18.8 (OG2008) years (Malina et al., 2013). The demands of the Olympic gymnastics have continued to escalate, and currently, a light, powerful, and usually, petite athlete is optimal (Arkaev & Suchilin, 2004).

Authors (Sands et al., 2012) state in the conclusion, that the US Women Olympic gymnasts were getting approximately smaller through the 1980s and early 1990s. Since then, the size of these gymnasts has increased. The minimum age rule modifications may have played a role in the athlete size changes along with a shift from the near dominance of the former communist Eastern Bloc (Sands et al., 2012).

In this research (Andreev, 2015) try to analyze different age aspects of 143 elite male gymnasts, Olympic medal holders for the time period 1960 – 2012. The average starting age to practice artistic male gymnastics is dropping more than 50% 14 to 6.2 from the beginning to the end of the researching time period 1960-2012. The average retirement age also has a trend of decreasing from the age of 36 to 26.4 or nearly 10 years. The average Olympic medal age is rejuvenating from 27 in Rome’60 to the age of 23.3 in London’12 and the “golden” age to earn the Olympic medal in male artistic gymnastics is 24. The rings are the “oldest” apparatus with an average age of 25.1 for medallists and the floor exercise is the “youngest”– 23.

Atiković, Delaš Kalinski and Smajlović (2017) in this study it was investigate the historical analysis of the chronological age trend of all participants of men’s artistic gymnastics who have won medals in the period between 1896 and 2016 has been made. The oldest gymnasts are on the Rings with an average age on (OG: M = 26.48, SD = 3.85) and (WC: M = 40.23, SD = 3.50) years old, and the youngest in the same are contestants (OG: Floor = 23.09, SD = 3.88) and (WC: M = 7.86 SD = 4.02). The results of independent *t* test were significant difference between OG and WC on Pommel horse (PH), Rings (RI), Paralell bars (PB), All-around individual (AAI) first place and Paralell bars (PB) first place.

Since artistic gymnastics becomes each Olympic cycle over more demanding in terms of complexity and difficulty value of the elements, it is expected fact that gymnasts and coaches need more time to acquire stability, experience and safety when performing such complex exercises. According to the first FIG CoP 1964 to the present, the MAG and WAG has already gone through 14 versions or cycles CoP. Atiković (2014) emphasizes that the changes in the regulation of men's and women's artistic gymnastics occur from one cycle to another by changes in evaluation of difficulty value (DV) from cycle to cycle: 1956-1976: A-C; 1979: A-C[r]; 1985-1989: A-D; 1992: A-E, 1996-7: A-E, 2001: A-super E; 2006: male: A- F, female: A-G; 2009: A-G, 2013 male: A-G, female: A-H. Every element was awarded a specific difficulty rating, ranging from A (easiest) to I (hardest) in the table of elements. Gymnast earned bonus points by performing difficult skills alone or in combination (FIG, 2017[a,b]).

The increased complexity of CoP, in terms of difficulty value and increased number of deductions, require gymnast's longer competitive internship, in order to be successful in the gymnastics community. Some gymnasts and gymnasts such as Oksana Chusovitina and Yordan Yovchev, succeeded the age of 40 to be ranked high in major competitions. Oksana Chusovitina competed at her seventh Olympics in year 2016, another record, at the age of 41. Bulgaria's Yordan Yovchev (39 years old) became the first male gymnast to ever compete in six OG.

The aim of this research is to analyze different age aspects of male and female participants at the Olympic Games and World Championships from 2003 until 2016, and to determine the differences in the age structures between particular competitions and disciplines in male and female artistic gymnastics. The studies concerning different age aspects among elite athletes sports longevity in seniors gymnastics.

METHODS

All the participants in MAG are presented in the following competitions: WC2003, N=318; WC2005, N=177; WC2006, N=278; WC2007, N=253; WC2009, N=243; WC2010, N=299; WC2011, N=262; WC2013, N=261; WC2014, N=311; WC2015, N=276; and in WAG: WC2003, N=224; WC2005, N=95; WC2006, N=223; WC2007, N=214; WC2009, N=146; WC2010, N=218; WC2011, N=216; WC2013, N=134; WC2014, N=250; WC2015, N=261. The sample of the examinees also included all the participants in MAG in the following competitions: OG2004, N=98; OG2008, N=98; OG2012, N=98; OG2016, N=97; and in WAG: OG2004, N=98; OG 2008, N=97; OG2012, N=96; OG2016, N=98. The total number of analyzed WC participants in MAG amounted to N=2678 and the WAG was N=1981; while at the OG with MAG N=391 and the WAG N=389.

We have made historical analysis of the chronological age trend from the official book results of the Fédération Internationale de Gymnastique (FIG) of all male and female participants in men's artistic gymnastics and women's artistic gymnastics for the period of 2003 to 2016.

The intent was to collect current data of female and male gymnasts from recent years. All data for this study was obtained from the Longines ranking website and official websites of the OG results Longines Official Results Books 2003 - 2016 http://www.longinestiming.com/#!/gymnastics/ (Accessed 1 Sep 2016) & Official Website of the Olympic Games Results 2004-2016 https://www.olympic.org/olympic-results (Accessed 1 Sep 2016). These two web pages record all gymnastics results according to events, such as WC and OG. We started collecting data from the WC2003 and ended with the OG2016, because previous data was not available for analysis or it was not complete. The following variables were included: date of birth, qualification date of the OG, qualification date of the WC.

Data processing in this research and the application of the statistically mathematical procedures were conducted in the program package of Microsoft Office Excel 2013 and SPSS 23.0 (SPSS Inc., Chicago, IL, USA). For calculating the chronological age the following formulas from the Microsoft Office Excel 2013 package were used.

For the total *number of days* of one's age since the date of birth until the first day of the competition qualifications:

Calculation formula = DATEDIF (A1; B1; "d") (1)

For the total *number of years* of one's age since the date of birth until the first day of the competition qualifications:

Calculation formula = DATEDIF (days x 0.0027397260273973 years) (2)

For the total *number of years, months and days* since the date of birth until the first day of the competition qualifications:

Calculation formula = DATEDIF (A1; B1; "Y") & "years", &DATEDIF (A1; B1; "YM")&" months, "&DATEDIF (A1; B1; "MD") &" days" (3)

Descriptive statistics for all variables were used. Linear regression methods and second-order polynomial equations were used to determine the best fit for the time series. Several time-series analysis methods were calculated and fitted to the historical data, along with the resulting regression equations and $R2$ values using Microsoft Excel 2013. The best model fit for the historical data was determined by the highest $R2$ value. An independent sample t test was calculated to determinate if whether there is a difference between the chronological age of the all participants of the Olympic Games 2004-2016 and World Championships 2003-2015. Differences in the mean values are treated as statistically significant when the calculated p value was lower than 0.05.

RESULTS

Table 1-2 shows the descriptive information about WC and OG, number of athletes, the year when the competition was held, median value, standard deviations, individually for each of the disciplines.

The results in Table 4 of independent t test were significant; t test (592) = 4.17, p = .00, indicates that there are significant differences between MAG WC03 (22.94±3.42, n = 318) and the scores at the MAG WC15 (24.25±4.17, n = 276). The results in Table 4 of independent t test were significant; t test (483) = 7.92, p = .00, indicating that there are significant differences between WAG WC03 (17.49±2.32, n = 224) and the scores at the WAG WC15 (19.59±3.33, n = 261). The results in Table 4 of independent t test were significant, t test (194) = 3.91, p = .00, indicating that there are significant differences between WAG OG04 (18.73±2.85, n = 98) and the scores at the WAG OG16 (20.79±4.36, n = 98). The results in Table 4 of independent t test were significant, t test (130) = -2.68, p = .00, indicating that there are significant differences between WAG TEAM04 (18.33±2.50, n = 72) and the scores from WAG TEAM016 (19.70±3.34, n = 60).

Table 1

Age (years) of the competitors (Mean ± SD) at the World Championships from 2003 to 2015.

	Year / Events	2003	2005	2006	2007	2009	2010	2011	2013	2014	2015
	N	318	177	278	253	243	299	262	261	311	276
Men	FX	22.68±3.35	22.61±3.46	22.81±3.80	23.26±4.00	22.63±3.13	23.12±4.06	23.73±3.91	22.93±3.57	22.90±3.35	23.89±3.93
	PH	22.97±3.44	24.51±3.20	23.14±3.84	23.51±4.07	22.78±3.24	23.33±4.09	23.75±3.85	23.18±3.87	23.16±3.63	24.13±4.18
	RI	22.93±3.43	23.62±3.85	23.07±3.96	23.63±3.99	22.93±3.63	23.44±4.17	23.89±4.05	22.79±3.69	23.05±3.42	23.86±4.03
	VT	22.84±3.44	22.80±3.55	22.91±3.86	23.23±4.01	22.77±3.45	23.27±3.92	23.89±4.02	22.63±3.48	22.06±3.55	23.99±4.07
	PB	22.92±3.42	23.56±3.78	22.95±3.92	23.69±4.16	22.84±3.47	23.37±4.23	23.81±4.02	23.06±3.97	23.04±3.57	24.03±4.13
	HB	22.88±3.42	23.34±3.77	22.94±3.88	23.55±4.11	23.19±3.70	23.34±4.16	23.90±3.94	23.17±3.75	23.10±3.59	24.04±4.11
	ALL MAG	22.94±3.42	23.63±3.69	22.99±3.94	23.51±4.16	23.30±3.67	23.54±4.19	23.95±3.99	23.82±3.89	23.23±3.67	24.25±4.17
	N	224	95	223	214	146	218	216	134	250	261
Women	VT	17.55±2.34	18.76±2.51	18.48±2.56	18.00±2.80	18.37±2.23	18.42±2.62	19.12±3.03	19.41±3.43	19.36±3.15	19.58±3.22
	UB	17.57±2.37	18.67±2.61	18.50±2.53	17.90±2.73	18.57±2.42	18.38±2.37	18.96±2.78	19.23±2.93	19.29±3.07	19.66±3.35
	BB	17.60±2.39	18.82±2.66	18.40±2.51	18.00±2.82	18.54±2.37	18.49±2.59	19.03±2.90	19.16±2.87	19.31±3.14	19.62±3.35
	FX	17.52±2.35	18.78±2.30	18.40±2.52	17.93±2.88	18.44±2.28	18.23±2.29	19.03±2.90	19.09±2.80	19.08±2.96	19.54±3.31
	ALL WAG	17.49±2.32	18.72±2.66	18.37±2.45	17.88±2.78	18.59±2.38	18.47±2.60	19.01±2.97	19.44±3.39	19.23±3.07	19.59±3.33

Abbreviations: N, Number of participants; M, Mean; SD, Standard deviation; FX, Floor; PH, Pommel horse; RI, Rings; VT, Vault; PB, Parallel bars; HB, High bar; UB, Uneven bars; BB, Balance beam; ALL MAG, All men competitors; ALL WAG, All female competitors.

Table 2
Age (years) of the competitors (Mean ± SD) at the Olympic Games from 2004 to 2016.

	Years Events	2004	2008	2012	2016
Men	N	98	98	98	97
	FX	24.13±3.17	24.39±3.1	24.32±3.70	24.58±3.62
	PH	24.51±3.20	24.63±3.18	24.60±3.58	24.49±3.50
	RI	24.59±3.21	24.57±3.36	24.56±4.00	24.51±3.44
	VT	24.21±3.12	24.55±3.27	24.23±3.89	24.69±3.61
	PB	24.44±3.22	25.05±3.50	24.70±3.83	24.51±3.42
	HB	24.36±3.04	24.74±3.25	24.64±3.69	24.76±3.88
	ALL MAG	24.61±3.25	25.06±3.49	24.97±4.09	25.24±3.87
	N TEAM	72	72	60	60
	TEAM	24.35±3.26	24.95±3.19	24.06±3.70	25.11±3.46
Women	N	98	97	96	98
	VT	18.61±2.80	18.98±3.05	20.41±3.75	20.41±4.12
	UB	18.72±2.65	18.88±2.94	20.22±3.43	20.32±3.37
	BB	18.59±2.54	18.89±3.25	20.31±3.59	20.92±4.46
	FX	18.50±2.52	18.98±3.09	20.29±3.36	20.49±3.78
	ALL WAG	18.73±2.85	19.01±3.03	20.43±3.65	20.79±4.36
	N TEAM	72	72	60	60
	TEAM	18.33±2.50	18.92±3.24	19.69±3.85	19.70±3.34

Abbreviations: N, Number of participants; N TEAM, Number of team participants; M, Mean; SD, Standard deviation; FX, Floor; PH, Pommel horse; RI, Rings; VT, Vault; PB, Parallel bars; HB, High bar; UB, Uneven bars; BB, Balance beam; ALL MAG, All men competitors; ALL WAG, All female competitors.

Table 3
Linear and Second-Order Polynomial-Regression Equations for Individual Athlete Data on Each Variable With the World Championships and Olympic Games Year.

Variable Age (yrs)	Linear equation	r2	Second-order polynomial equation	r2
MAG 2003-2016	$y=0.071x+23.402$	0.146	$y=0.0058x^2-0.016x+23.634$	0.158
WAG 2003-2016	$y=0.1696x+17.715$	0.628	$y=0.0083x^2-0.0449x+18.048$	0.647
MAG OG 2004-2016	$y=0.1386x+24.277$	0.129	$y=-0.1151x^2-0.4371x+24.853$	0.200
WAG OG 2004-2016	$y=0.4872x+17.946$	0.903	$y=-0.1448x^2-1.2114x+17.222$	0.967

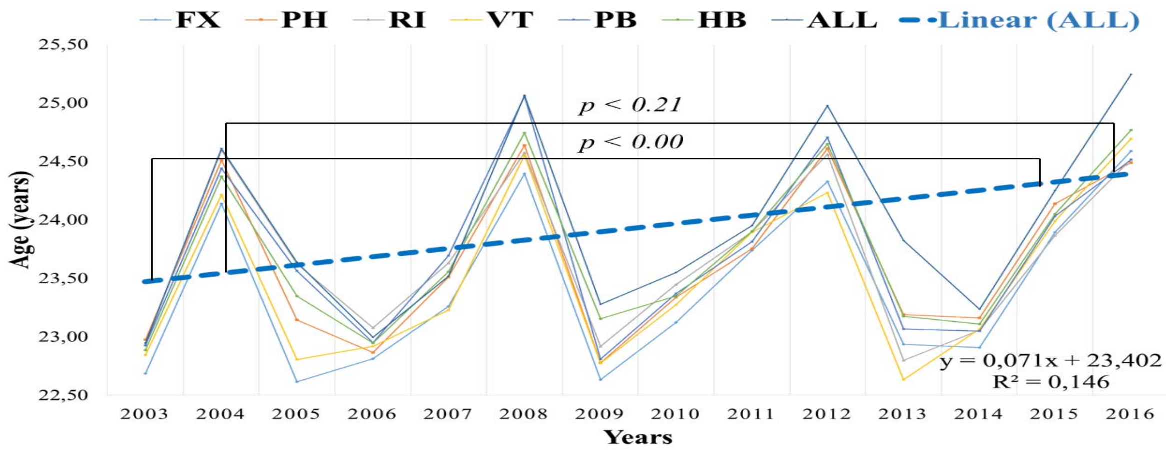
Abbreviations: MAG 2003-2016, Men's artistic gymnastics results; WAG 2003-2016, Women's artistic gymnastics results; MAG OG 2004-2016, Men's artistic gymnastics results Olympic Games; WAG OG 2004-2016, Women's artistic gymnastics results Olympic Games.

Table 4
Independent t-test for Equality of Means.

Event	N	Mean±SD	N	Mean±SD	t	df	p
MAG WC03-WC15	318	22.94±3.42	276	24.25±4.17	4.17	592	0.000*
MAG OG04-OG16	98	24.61±3.25	97	25.24±3.87	-1.23	193	0.218
WAG WC03-WC15	224	17.49±2.32	261	19.59±3.33	7.92	483	0.000*
WAG OG04-OG16	98	18.73±2.85	98	20.79±4.36	3.91	194	0.000*
MAG TEAM04-16	72	24.35±3.26	60	25.11±3.46	-1.29	130	0.197
WAG TEAM04-16	72	18.33±2.50	60	19.70±3.34	-2.68	130	0.008*

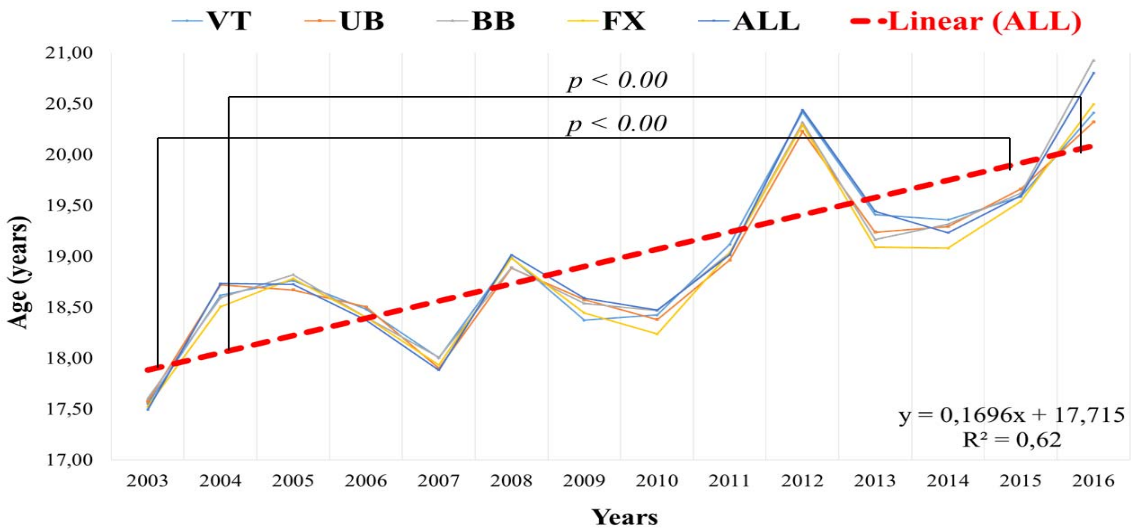
Abbreviations: N, Number of Participants; M, Mean; SD, Standard deviation; t = t test value, df = Degrees of Freedom, *p, indicates a statistically significant difference at p<0.05; MAG, men's artistic gymnastic; WAG, women's artistic gymnastics; WC, World Championship; OG, Olympic Games.

Figures 1 through 3 show the age of the competitors and teams (Mean ± SD) at the WC and OG 2003–2016. Figures 1 through 3 also show the linear fit curves.



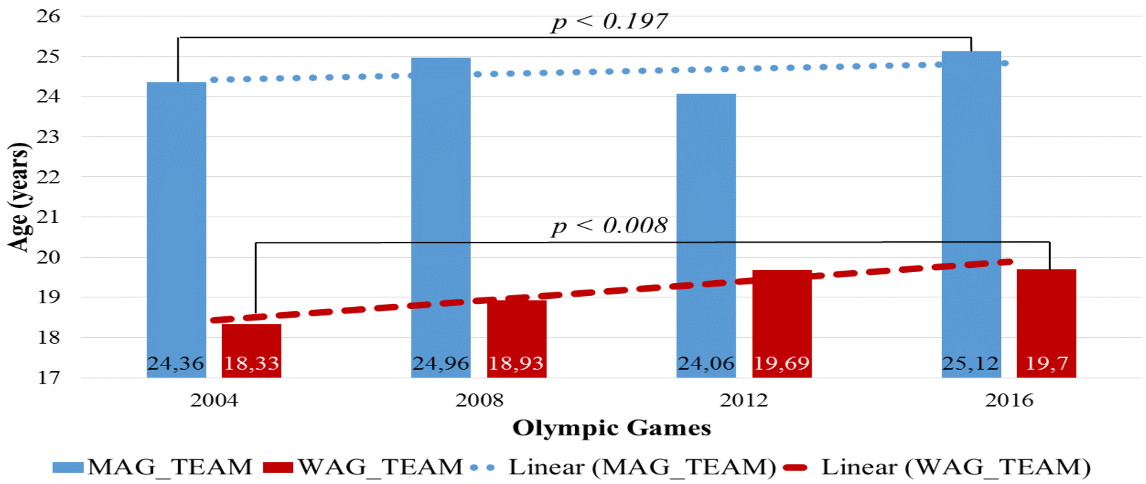
Abbreviations: p, statistically significant difference at p<0.05; FX, Floor; PH, Pommel horse; RI, Rings; VT, Vault; PB, Parallel bars; HB, High bar; ALL, All men competitors; ALL Linear, Linear regression.

Figure 1. Trending ages of men's artistic gymnastics gymnasts from 2003 to 2016.



Abbreviations: p, statistically significant difference at p<0.05; VT, Vault; UB, Uneven bars; BB, Balance beam; FX, Floor; ALL, All women competitors; ALL Linear, Linear regression.

Figure 2. Trending ages of women's artistic gymnastics gymnasts from 2003 to 2016.



Abbreviations: p, statistically significant difference at p<0.05; MAG and WAG all team participants at the Olympic Games; ALL Linear, Linear regression.

Figure 3. Trending ages of men's artistic gymnastics and women's artistic gymnastics team gymnast from 2004 to 2016.

DISCUSSION

In Table 1, the youngest male participants at the WC were recorded in six occasions on the FX 2003-2006 and 2009-2011, then three times on the VT 2007, 2013 and 2014. The youngest female participants at the WC were recorded six times on the FX 2003, 2006, 2010, 2013-2015, three times on the UB 2005, 2007 and 2011. The oldest male participants at the WC were recorded six times on the PH from 2003-2006, 2013-2015, and two times on the HB in 2009 and 2011. The oldest women at the WC were recorded four times on the BB 2003, 2005, 2007 and 2010, three times on the VT 2011-2014.

In Table 2, the results presented are the ones from the oldest male participants of the OG. The oldest were on the PB in 2008 and 2012, while the oldest female was equally represented on all four competitions of the OG. The youngest male participants of the OG ware recorded twice on the FX at the OG in 2004 and 2008, while youngest female were recorded three times at the UB 2008-2016. When we look at the values of all twelve participating teams at the OG in MAG and WAG, we can notice a slight tendency of age growth in both competitions.

In Table 3, we have the presented equations for the least-squares best fits of linear and polynomial-regression equations. Note that the general trend over time appears to be a simple linear relationship. The values *R*2 are more expressed in WAG compared to MAG both for team competitions and each year and discipline.

Comparing to Rozin & Čeburaev (1981) results from that period and the newer dates, we can see that the gymnasts were older than they are today at the OG and even then we can notice a slight decrease in the age of the athletes. Gaverdovskij (1983) analyzed trends in gymnast's age and their competitive career; his main conclusion was that the age of top gymnasts is lowering and time of their career is shortening according to their peers between years 1950-1980. However, change of CoP, age limitation changed that rule severely (Figure 4), as gymnast's career is longer, their age is rising again.

Age changes occur systematically from Olympic cycle to cycle. The oldest competitors are at the OG, then there is a decline in the trend of one or two years, and again at the end of the Olympic cycle trend is returning to a higher value than the previous cycle. It should be noted, that for all countries it is the most important competition at the OG. Year after OG, and that in particular, the WC serves as opportunity for young gymnasts to prove themselves on the international scene. Granting, the trend is not reflected to change a whole generation of competitors. In regard to this, it should be noted that the male all-around competitors however are the oldest; and that there are age differences between disciplines in men more than in female, where these differences are very small between disciplines. Based on the arguments presented in the text, it is evident that there has been an increase in the age of more women's artistic gymnastics than in men's artistic gymnastics. The male gymnast from 2003 to 2016 are, on average, older for 2.3 years and for female it is 3.3 years of age and the growth trend continues. Unlike men, women have statistically significant difference in age for the period OG from 2004 to 2016. For women, it is noticed faster uptrend age from Olympic cycle to cycle. International Gymnastics Federation may increase the minimum age of female participants from the current 16 to 17 years old.

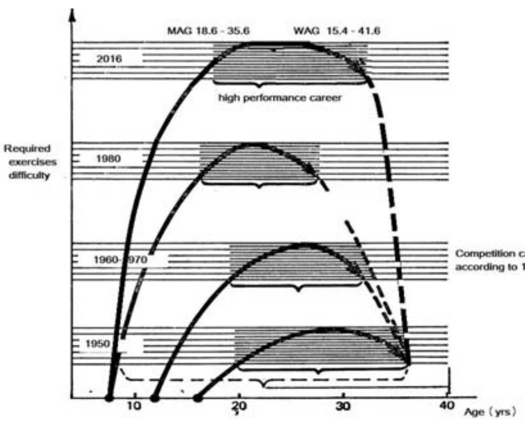


Figure 4. Time of competition career during decades (adopted year 2016, acording to Gaverdovskij, 1983).

We can compare our results with McCready (2016) research "For Olympic Athletes, Is 30 the New 20?". According to McCready, it's no secret that gymnasts across the border and in different countries are getting younger, but we were not aware of the magnitude. Although they have an average age of 23.4 years, which is almost the same as the full study average, it was mainly boosted in the first half of the century. For instance, the average age of gymnasts before the 1960s was above 26 years of age, bringing the average age up significantly. But that trend was about to be busted in a big way in just a few years. During the latter half of the 1960s, we first see the downward trend starting at 23 years of age and continuing until it hits rock bottom at 18 years of age in 1992. After that low point in 1992, the average age settled in at around 21 years of age for the next 20 years. He predicts that the trend will continue into 2016, with the average gymnast being closer to 20 years of age. He looked at the 1952 Olympics and onward because female were not able to compete in Gymnastics prior to 1952. Male gymnasts have been well above the average age trend line since 1952. It almost mirrors the average age trend line in slope for the entire graph, starting with an average age of close to 27 and finally settling at the predicted age of about 22 years of age for 2016. On the other hand, the trend line for female gymnasts takes more serious and maybe even controversial downward push. Starting at almost the exact same age as the combined trend line of 24.4 years, their trending ages drop almost nine years before finally settling on a projected average of about 16 years of age in 2016 (McCready, 2016).

According to the results presented in Table 4, male participants are getting older at WC2003 – WC2015 but on the OG are not older than before OG2004 – OG2016 (Figure 1). Women are getting older, and among them was a statistically significant change relations to the years WC2003 – WC2015 and OG2004 – OG2016 (Figure 2). Also, for male members of the team, there is no significant difference OG2004 – OG2016, while for women there is a difference between OG2004 – OG2016 (Figure 3).

If we compare the age of the MAG by disciplines, the oldest gymnasts are on rings, and the youngest are on the floor. Static strength is required on the rings; it is obvious that for getting it, a certain period of training is required, according to those needs that the best results on rings are expected only after the age of 25 years. This can be explained with shorter amplitudes of movement on the rings in relation to other disciplines, which means that the body of gymnast is exposed to another type of stress and physiological damage compared to the exposure on other apparatus. Specialists on rings have a longer competitive career and higher amount of won medals: OG, 1960 Rome Albert Azaryan 31.56 years (URS), 1936 Berlin Leon Štukelj 37.71 years (YUG), 2004 Athens Jury Chechi 34.86 (ITA), WC 2002 Debrecen Szilveszter Csollány 32.71 years (HUN), 2009 London Yordan Yovtchev 36.65 years (BUL), 1909 Luxembourg Frantisek Erben 34.70 years (BOH), etc...

MAG and WAG gymnasts on floor expose their body to extremely body and training load. Probably for this reason, it is not surprising that gymnasts on the floor achieve their best results, on average, at the OG and WC at the age of 23 years (male) and 19 (female). Nunomura (2002) reported that each apparatus presents their unique characteristics. Moreover, in recent years, complexity increased in their implementation and motor demand, the fact that determined the increase in daily training hours (Nunomura, 2002, Caine, 2013). According to the author (Nunomura, 2008), floor is the one most complex apparatus in artistic gymnastics and it is composed of acrobatic elements combined with gymnastic strength and balance exercises. Floor exercise demands are linked to strength (muscle power in the lower and upper limbs), flexibility, and muscular anaerobic endurance. Forces experienced during take-offs and landings in artistic gymnastics can be very high. Forces measured at landings can range from 3.9 to 14.4 times the gymnast's body weight (Panzer, 1987; McNitt Gray, 1993). The highest forces measured when performing double back somersaults ranged from 8.8 to 14.4 times the gymnast's body weight. This was 6.7 times more body weight compared to back somersault. Karacsony and Čuk (2005) found that forces at take off at different somersaults can be up to 13.9 times the participant's body weight. This is one of the reasons short sports career at the floor on the top level.

Due to the relevance of the sample, the data obtained in this research can serve as the orientation values in guiding and shaping gymnasts in specialization to the particular apparatus, or all-around. In addition, data on the age will serve coaches in the process of planning the training and timing sports form, that is, the expectations of maximum results, given the age of their gymnasts. All top gymnasts are very similar, but some minor differences are registered Karacsony and Čuk (2005). The average age of those competitors who take first place by disciplines is registered and by large competitions which was not the case in the former literature. Obtained results showed some, statistically, significant differences and to similar data for the two directions for giving points came (Možnik, Hraski, & Hraski, 2013).

With the changing appearance vault and its specification since WC 2001 WAG, there is a possibility for gymnast specialists on that apparatus to remain active as competitors for a long period of time. It is no coincidence that the oldest contestants in the discipline are women. Some of the competitors are: OG - 1952 Helsinki Ekaterina Kalinchuk 29.65 years (URS), 2008 Beijing Oksana Chusovitina 33.16 years (GER), 1956 Melbourne Olga Lemhényi-Tass 27.67 years (HUN), WC - 1950 Basel Helena Rakoczy 28.58 years (POL), 2011 Tokyo Oksana Chusovitina 36.33 yeras (GER), 2006 Aarhus Oksana Chusovitina 31.34 years (GER), etc.

We know that there are probably many intersecting factors moving the ages upwards or downwards and therefore we would mention most evident: training loads, increased number of competitions, changing number participants per events, sponsorship deals and rewards for medals. Results on changes in age, should contribute to a better overview and planning of the prosperity of individual gymnasts in order to ensure the best prognostics of their top achievements in specific disciplines.

CONCLUSION

According to the results presented and discussed herein, the following conclusions are:

- in the last 15 years there has been a linear increase in the age structure of participants in MAG and WAG at the WC 2003 - 2015.
- at OG there have been significant age change at WAG between 2004 and 2016.
- at OG between 2004 and 2016 individual men age rose, but non significantly; similar is valid also for members of teams at OG.

- changes in the General Rules and Code of Points by FIG have significantly influenced age rise compared to the previous Olympic cycles.
- male and female gymnasts ended their carriers earlier in the past, while today we have some athletes in professional gymnastics who are over 35 years of age.
- as it can be noted, in the past, there was a noticeable downward trend in age of both male and female participants of the OG. In the upcoming period, we do expect that (with apparatus specialization) the age will be slightly higher.

In future studies, it would be preferable to analyze whether these increases in the age trend, in any way, relate also to the medalists of the OG and WC. Future studies should conduct the analysis between the medalists and non-medalists in gymnastics and make differentiations according to the disciplines of both genders.

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MENTAL REPRESENTATIONS IN PHYSICAL EDUCATION STUDENTS' EVALUATION OF GYMNASTICS SKILLS

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Original article

Abstract

Research provides evidence that mental representations control human actions. It also shows a relation between mental representations and factors that might influence performance evaluation. The evaluation of motor skills figures prominently in physical education (PE) because it influences central tasks of teachers, like the provision of feedback and grading. Therefore, the purpose of this study was to examine the relation of PE students' mental representation structures and their evaluation of pupils' gymnastics skill performance. Mental representations and performance evaluations of the cartwheel and the roll forward were assessed in N = 30 PE students, by means of structural dimensional analysis - motoric and a video test. Participants' mental representations and performance evaluations were compared to an expert reference. Results revealed significant differences regarding the comparison of performance evaluations for a group of participants with more structured and a group with less structured mental representations, indicating that more structured mental representations are linked with a more precise performance evaluation. The study demonstrates that there is a relation between PE students' mental representation structure and their evaluation of gymnastics skills. Consequently, it is proposed to implement obligatory physical and mental training in the gymnastics training for future PE teachers, in order to develop expert-like mental representation structures and improve performance evaluation.

Keywords: *performance evaluation, SDA-M, roll forward, cartwheel.*

INTRODUCTION

The evaluation of motor performance is one of the central tasks of various actors in sports, such as coaches, referees, judges or teachers in physical education (PE). Observers' ability to evaluate performance influences the provision of feedback, affects the grading of pupils and can decide on victory and defeat in competitions (Nicaise, Cogérino, Bois, & Amorose, 2006; Plessner & Haar, 2006). Therefore, it is important to examine the processes that are taking place during performance evaluation more closely.

According to literature, the following four steps might characterize the evaluation of performance: 1) observation of the movement, 2) perception of the movement, 3) actual–target comparison, 4) detection of errors (Jeraj, Hennig, & Heinen, 2015). For a teacher in PE who has to evaluate the skill performance of a pupil, these steps could proceed as follows: In a first step, the teacher observes pupil's skill performance and perceives a large amount of visual information. In a second step, this information has to be processed in the teacher's mind. The third step could be described as an actual-target-comparison, the comparison between real and expected performance of the learner, which leads to the fourth step, error detection. Strengths of the performance, as well as the weaknesses or errors, have to be established so that the teacher is able to judge learner's skill performance (Cloes, Hilbert, & Piéron, 1995; Cloes, Premuzak, & Piéron, 1995; Knudson, 2013). It is suggested that during the third step of performance evaluation the visual perceptions of body positions are compared to mental representations of expected body positions throughout each phase of the movement (Hay & Reid, 1988). This focusing on the difference between the actual performance and a model of good form leads to error detection (Knudson, 2013). Thus, one important factor that influences performance evaluation might be observers' mental representation structure of the skill to be evaluated, because mental representations in long-term memory act as a type of reference base for the planning and organization of behavior and are of utmost importance for the organization of motor actions (Bläsing, Tenenbaum, & Schack, 2009; Williams, Davids, & Williams, 1999). This is why the purpose of this study was to answer the question if performance evaluation is directly influenced by mental representations.

Theoretical approaches, such as the *theory of event coding* (Hommel, Müsseler, Aschersleben, & Prinz, 2001) and the *ideomotor approach* (Knuf, Aschersleben, & Prinz, 2001) emphasize the role of (mental) effect representations as the basis for intentional behavior (Hommel, 1996). These action-effect associations are excitable in both directions. It is, for instance, thought that the execution of a movement activates representations of a sensory effect and the excitation of an effect representation causes the execution of a movement (Kunde, 2006). Thus, the observation of learned movements leads to an activation of certain neural structures in comparison to unlearned movements (Cross, Hamilton, & Grafton, 2006). Further on, results showed an activation of similar neural structures during observation of movement patterns similar to the own field of expertise and a higher activation during observation of movement patterns identical to the own field of expertise (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005). Complex movements can thus be conceptualized as a cognitive network of sensorimotor information (Schack, 2004). The nodes within this network contain functional subunits (*Basic Action Concepts*; BACs) that are related to motor actions. Results from different lines of research addressing mental representation highlighted that the structure formation in long-term memory is built up on BACs. They are created through cognitive chunking of body postures and movement events concerning common functions in realizing action goals and include perceptual (visual, auditory, kinaesthetic) data and semantic content (Bläsing, 2010; Schack, 2010a). The better the order formation of these nodes, the easier information can be accessed and retrieved, leading to improved motor performance (Land, Volchenkov, Bläsing, & Schack, 2013). According to the *Cognitive Architecture Action-Approach* (Schack, 2004, 2010b) BACs are functional units for the control of actions at the level of mental representation. The level of mental representation is based on declarative as well as non-declarative knowledge in long-term memory (Bläsing, 2010).

To investigate the nature and role of long-term memory structures in complex motor performance, Schack and Mechsner (2006) examined the tennis serve. It was revealed that experts showed an organized hierarchical tree-like structure that was similar between individuals and was well matched with the functional and biomechanical demands of the task. Novices' mental representations were organized less hierarchically, more variable across individuals and less well matched with functional and biomechanical demands. Other studies replicated these results for example in the domains of dancing (Bläsing et al., 2009) and judo (Weigelt, Ahlmeyer, Lex, & Schack, 2011), supporting that mental representations differentiate between novices and experts and match to functional and biomechanical task demands. Supplementary, a study by Frank, Land, and Schack (2016) examined changes in the mental representation structure and outcome performance over the course of skill acquisition incorporating physical and mental practice. Their results show improvements in golf putting performance and a functional adaption of the mental representation structures across a physical practice group and a combined physical plus mental practice group.

If mental representations are the basis of action organization, they might be a basis of evaluation processes as well and thus might be a valuable indicator of expertise in performance evaluation. Advantages of experts in comparison to novices in skill execution may be traced back to more structured mental representations that facilitate movement execution, movement perception and anticipation of movement effects (Aglioti, Cesari, Romani, & Urgesi, 2008). Mann, Williams, Ward, & Janelle (2007) argue that experts have better domain-specific knowledge structures (i.e., mental representations) that optimize the picking up and processing of information (Gegenfurtner, Lehtinen, & Säljö, 2011).

Jeraj, Veit, Heinen, and Raab (2015) investigated factors that might be influencing the feedback process, which contains the above mentioned four steps of performance evaluation. For example, they list motor experience and biomechanical knowledge, factors that are related to mental representation structures. That is, athletes with higher motor experience and thus expertise show a better structured mental representation that matches with the biomechanical demands of the motor action (Schack & Mechsner, 2006).

In a study by Pizzera (2012), gymnastics judges were asked to rate gymnasts performing a balance beam skill regarding pre-determined criteria in a video test. The aim of the study was to investigate how gymnastics judges utilize their own experiences in the sport as sources of information. Decision quality between judges who could perform the skill on the balance beam themselves, thus have motor experience in this specific gymnastics skill, and those who could not was compared using a reference score. Results showed that judges with specific motor experience perform better than those without. In addition, Heinen, Vinken, and Velentzas (2012) concluded that judging in gymnastics could be facilitated by either own motor experience or specific visual experience. When judging handsprings, laypeoples' scores were in average lower than gymnastics judges' scores. Considering the results of Pizzera (2012) and Heinen et al. (2012) that motor experience leads to a more precise performance evaluation and the aforementioned relation of mental representations and motor experience, one could assume that a better structured mental representation might lead to a more precise performance evaluation as well.

Additionally, Hoffman and Sembiante (1975) asked baseball coaches, physical educators, and a control group to analyze the swing in baseball. The results showed a

74 % accuracy in diagnosing the swing for coaches, a 66 % accuracy for physical educators and a 44 % accuracy for the control group. No significant differences could be found between groups when analyzing a novel skill. These results suggest that performance evaluation is a function of skill familiarity, which in turn points to biomechanical knowledge. This strengthens the probable link between mental representations and performance evaluation since skill familiarity can be associated with a more structured mental representation of the skill (Land et al., 2013).

Another point of consideration for evaluation of performance is the task that has to be evaluated. Schack and Hackfort (2007) describe that every movement can be broken down into its structure and process, which implies the significance of the constituent parts of an action. Differences in structure and process of tasks may determine their difficulty. Studies could show a relation between task difficulty and strategies used by participant to solve tasks (e.g., Wulf, Töllner, & Shea, 2007). Hennig, Velentzas and Jeraj (2016) presented a study that determined possible differences between display formats of items used in *structural dimensional analysis - motoric* (SDA-M) in gymnastics. In this context they could show a task-related difference in difficulty, because solutions for the roll forward (a simpler task) were more similar to an expert structure than solutions for the cartwheel (a more complex task).

As the literature review indicates, mental representations control motor actions. Because perceiving and acting rely on the same representations, it is presumable that the evaluation of motor actions, or more specifically the actual-target-comparison, relies on these representations as well (Hommel, 1996). Thus, it would be important to know if observers' mental representations of a motor skill influence their performance evaluation. Furthermore, mental representations compose the knowledge base for human actions and are related to factors that might influence the evaluation process, such as motor experience (Schack & Mechsner, 2006). This is why it was assumed in this study that observers with better structured mental representations show a more precise performance evaluation as well. The aim of this study was to analyze the relation between PE students' mental representation structure and their evaluation of pupils' skill performance, addressing the question, if it is possible to show a direct link between mental representation structure and performance evaluation by means of the SDA-M.

Therefore, PE students were asked (1) to fill in two SDA-M questionnaires to assess their mental representation structure of the cartwheel and the roll forward, and (2) to rate videos of pupils performing a cartwheel and a roll forward. Two groups of participants were determined based on SDA-M results. Distinguishing criterion for the division of groups was the similarity of participants' mental representation structure to an expert reference structure. Thus, one *similar* (to mental representation structure of experts) group and one *dissimilar* (to mental representation structure of experts) group of participants were distinguished. Following the aforementioned argumentation, it was hypothesized that an expert-like mental representation structure has a positive influence on the performance evaluation. The more similar the PE students' representation structure to an expert reference structure, the more similar the performance evaluation of the motor skills to an expert rating. Or in other words, the better the mental representation structure, the better should be the performance evaluation. However, regarding the two skills cartwheel and roll forward, it was hypothesized that there is a task-specific difference in difficulty (Gerling, 2011; Hennig et al., 2016).

METHODS

In total, *N* = 30 PE students (pre-service PE teachers) (age: *M* = 22.80 years, *SD* = 2.40; gender: 18 male, 12 female) participated in this study. All participants were studying to receive their Master's degree to become teachers for PE. Representing a rather homogenous group of future teachers, participants were chosen, who were about to finish their studies and therefore on an approximately equal educational level. Prior to the beginning of the study, all participants were informed about the general procedure and gave their written consent. The study was carried out according to the ethical guidelines of the university's ethics committee.

Structural Dimensional Analysis - Motoric. To PE students' mental representations of the gymnastics skills cartwheel and roll forward, the *structural dimensional analysis - motoric* (SDA-M; Schack, 2012) was used. This experimental approach, permitting a psychometric analysis, proved itself as a reliable method to determine relations between functional sub-steps of a movement (*basic action concepts*; BACs) and the groupings of a given set of BACs (Velentzas, Heinen, Tenenbaum, & Schack, 2010). In a first step, a split procedure (see the following paragraph) on a set of BACs is performed, resulting in a distance scaling between the BACs. For the purpose of this study, a pre-determined set of eight BACs relating to the cartwheel and a set of seven BACs relating to the roll forward were used. Both sets of BACs were generated based on expert interviews and textbooks (see Hennig et al., 2016). In a paper-pencil questionnaire, pairs of two BACs are presented in randomized order, so that each of the BACs is being displayed together with another BAC (see Figure 1 as an example). Participants are asked to decide whether the two BACs presented together are related to each other during movement execution or not. To do so, participants chose either a negative or positive sign in the paper-pencil test. The splitting task is completed after each BAC has been compared to every other BAC of the set, so the questionnaires consisted of 21 item comparisons for the roll forward and in total 28 item comparisons for the cartwheel.

Video Rating for Performance Evaluation. To assess performance evaluation of the participants, a video test for each skill was conducted. Therefore, 19 seventh-graders were asked to perform both skills, the cartwheel and the roll forward, before and after a training phase. The video tests included a playlist of 38 video clips for the cartwheel and 38 video clips for the roll forward in randomized order. Each video clip was only shown once and participants were not able to pause or repeat the video clip to simulate real PE conditions. Participants scored the quality of each performance of cartwheel and roll forward with regard to a given set of criteria on a 10-point scale. Table 1 and Figure 2 illustrate the criteria for the evaluation of the two gymnastics skills. For each point of the mentioned criteria the pupil in the video fulfilled, participants noted one point on an evaluation sheet. Both skills could be scored with a maximum of ten points (pupil met the skill criteria in every point) and a minimum of zero points (pupil made major movement errors, not meeting skill criteria in any point).

Reference Structure and Gymnastics Skills. A group of four gymnastics experts was asked to participate in this study. Their mental representation structures, as well as their evaluation of pupils' performance of gymnastics skills, were determined as point of reference (see Data Analysis section). The experts reported *M* = 14.75 years of experience as gymnastics coaches. Experience and the ability to evaluate performance was the selection criterion for expertise in this study (Chi, 2006; Swann, Moran, & Piggott, 2014).

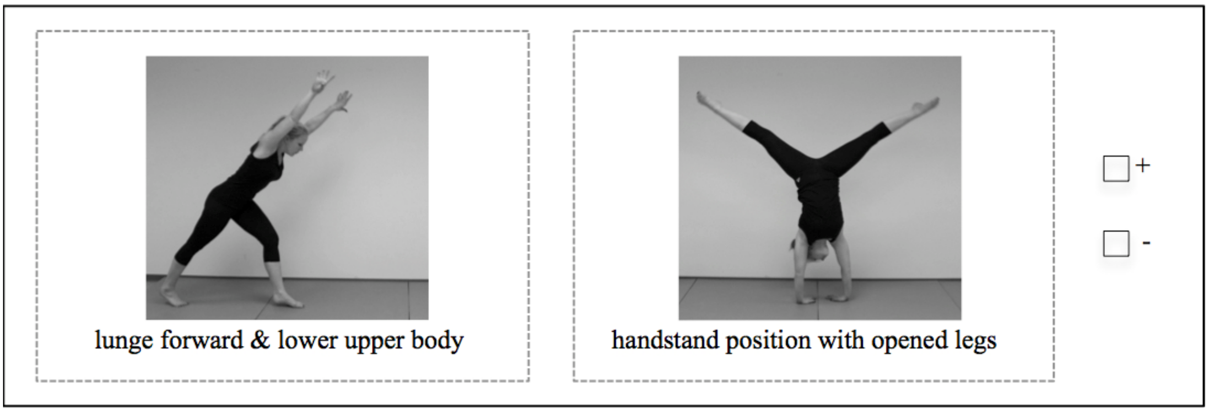

Figure 1. Example for one of the 28 item comparisons of the SDA-M questionnaire for the cartwheel. Participants had to choose either the negative or positive sign depending on whether the two BACs presented are related to each other during motor performance or not.

Table 1
Evaluation Criteria for the Judging of Pupils' Performance for the Gymnastics Skills Cartwheel and Roll Forward (see Figure 1).

No.	Cartwheel	Roll Forward
1	Standing straight & raising arms	Standing straight & raising arms
2	Twisting upper body	Squatting down
3	Positioning hands aligned on the floor one after the other	Putting arms forward shoulder width
4	Pulling up legs one after the other	Taking head to chest
5	Straightened legs and arms & body tension	Rolling in upper body
6	Handstand position with open legs	Placing back of the neck
7	Placing feet one after the other on the floor	Moving knees to chest
8	Setting body upright	Placing feet on the ground
9	Standing on both feet & balance	Standing up without using hands
10	Fluent movement sequences	Fluent movement sequences

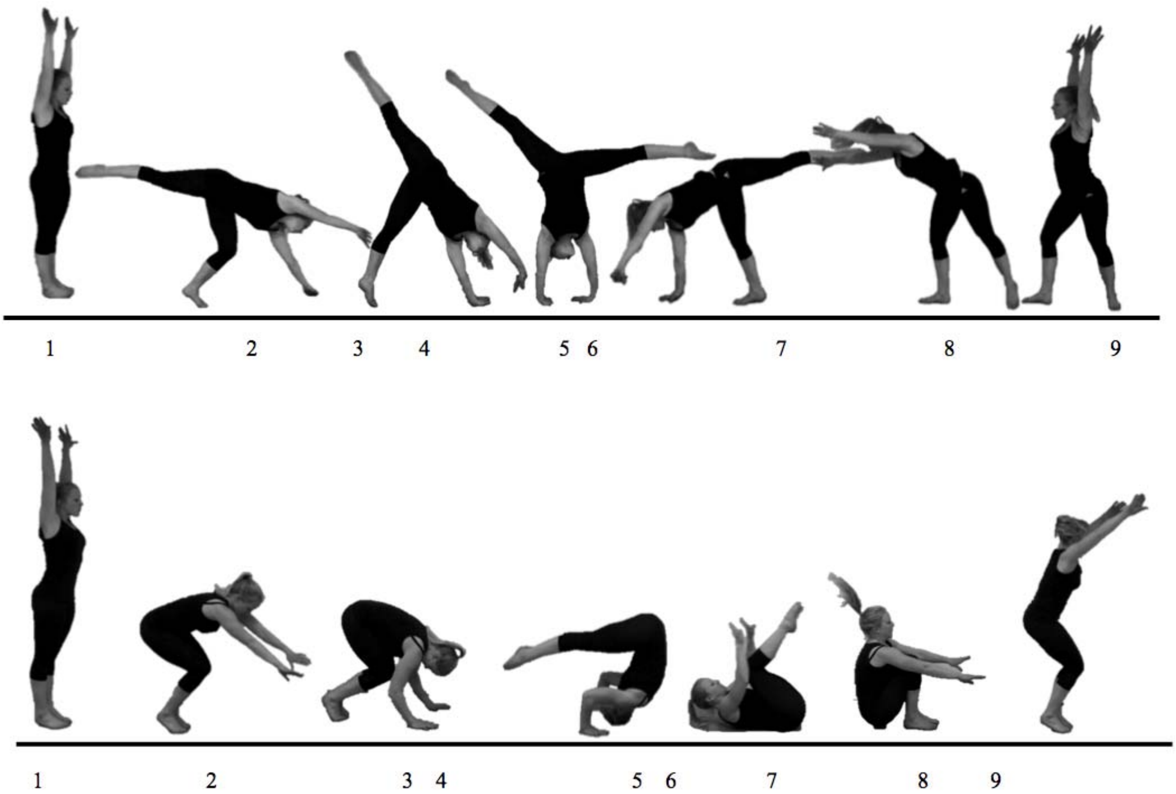

Figure 2. Sequences of pictures for the two gymnastics skills cartwheel (top) and roll forward (bottom), illustrating points one to nine of the evaluation criteria for the judging of pupils' performance (see Table 1). Point ten of the evaluation criteria refers to the whole movement and is not explicitly mentioned in this Figure.

The cartwheel and the roll forward were chosen to exemplify a more complex and a more basic floor exercise in gymnastics. While the roll forward is executed in the sagittal plane around a horizontal axis, the cartwheel includes rotations of the body around the longitudinal and the anteroposterior axis (Gerling, 2011; Figure 2). Both skills are part of the German curriculum of PE for Lower Saxony, in the experience and learning field of Gymnastics and Movement Arts that contains rolling, swinging, jumping and balancing (Ministry of Education and Cultural Affairs of Lower Saxony, 2007).

The study was conducted in the local university, where participants were asked to meet in a seminar room. Participants were informed about the general purpose and procedure of the study and completed the informed consent form as well as a questionnaire on their own experiences as former gymnasts. To ensure anonymous participation, an ID was used on the questionnaires. In order to avoid sequential effects, the procedure was realized in two phases with two sub-phases each, which are described in the following. The first group of participants (n_1 = 15) began with the cartwheel and proceeded with the roll forward, the second group of participants (n_2 = 15) began with the roll forward and proceeded with the cartwheel.

First, participants were instructed to fill in the SDA-M questionnaire for one of the skills (cartwheel or roll forward). In the SDA-M the subjects were asked to state for each of the BACs involved in performing the appropriate gymnastics skill whether it is functionally close to each of the other BACs or not. Participants chose either a negative sign (minus) or positive sign (plus) in the paper-pencil test depending on whether the element was judged as belonging to or not belonging to the reference (for further details see Schack & Mechsner, 2006).

In the second step, participants were instructed to read the given criteria according to which they would evaluate the skill. The playlist of videos was presented via laptop and data projector, presented on the wall in front of them. After the presentation of one reference video for the skill, participants had to rate 38 randomly presented video clips for the cartwheel and for the roll forward. They watched the video clip, which was shown only once in real time, and then noted their ratings in the appropriate columns on the evaluation sheet.

A significance criterion of α = 5 % was defined a priori for all reported results. In order to test the main hypotheses, two separate *t*-tests for independent means were calculated. Cohen's *d* was calculated as an effect size for all reported *t*-values. Data were further analyzed in four steps:

First, for all SDA-M data collected, the splitting procedure (see Instruments) was applied. As a following step, a hierarchical cluster analysis was carried out to outline the structure of the given set of BACs (for details on SDA-M analysis, see Schack, 2012). In order to calculate the similarity/dissimilarity to the expert reference structure, the Euclidean distance for the comparison of each participant's *z*-matrix solution with the mean experts' *z*-matrix solution was calculated. To ensure comparability of the results for the different skills, the Euclidean distances of the comparisons were divided by the number of BACs (7 for the roll forward; 8 for the cartwheel).

Second, Euclidean distances were arranged according to size, so that two groups could be separated by median split: one *similar* (to mental representation structure of experts) group and one *dissimilar* (to mental representation structure of experts) group of participants. Thus, the *similar group* represents the group of participants with more structured mental representations and the dissimilar group represents participants with less structured mental representations.

Third, ratings in points for each video were arranged according to score, to compile a ranking with the best-rated video on first position and the video with the lowest rating on last position. In order to calculate the deviation to the reference performance evaluation, the mean of deviation from the reference ranking was calculated for each participant's ranking. Following, means and standard deviation of deviation of rankings for each group were calculated. A smaller deviation of rankings represents a more precise evaluation of the skills.

Fourth, in order to examine statistical differences between groups and tasks, *t*-tests for independent samples were conducted: An independent-samples *t*-test with *performance evaluation* as dependent variable and *mental representation structure* as independent variable (with the two groups: similar and dissimilar) for each task, the cartwheel and the roll forward. Furthermore, an independent-samples *t*-test with *performance evaluation* as dependent variable and *task* as independent variable (with the two groups: cartwheel and roll forward).

RESULTS

As a relation between mental representation and performance evaluation was assumed, both for the cartwheel and the roll forward, it was hypothesized that the more similar the PE students' representation structure to an expert structure, the more similar the performance evaluation should be to an expert rating. For the comparison of the results of a similar and a dissimilar group of PE students it was therefore hypothesized that there is a significant difference between groups. To verify this assumption, means and standard errors of deviation of rankings for a similar and a dissimilar group were calculated and in order to examine statistical differences between the two groups for the cartwheel and the roll forward, independent-samples *t*-tests were conducted.

Figure 3 displays that for the cartwheel as well as for the roll forward, the similar group shows closer values to the reference than the dissimilar group. Results of the *t*-tests revealed significant differences for the comparison of similar and dissimilar group for the cartwheel $t(28) = 1.729$, $p = .047$, Cohen's $d = 0.654$ and for the roll forward $t(28) = 2.234$, $p = .017$, Cohen's $d = 0.844$.

Regarding the comparison of the two skills cartwheel and roll forward, it was hypothesized that there is a task-specific difference. Means and standard deviation ($M \pm SD$) of the *performance evaluation* (deviation of the experts' ranking in points) for the two skills show that the deviation of the experts' ranking for the roll forward (1.315 ± 0.449) is smaller than for the cartwheel (1.603 ± 0.229). Results of the *t*-test showed a significant difference for the comparison of cartwheel and roll forward $t(28) = 3.154$, $p = .002$, Cohen's $d = 0.808$.

Overall, results displayed that the more similar the PE students' mental representation structure of the gymnastics skill compared to an experts' mental representation structure, the more similar the performance evaluation of this skill compared to an experts' performance evaluation. Regarding the tasks, results revealed that participants showed a significantly lower deviation from expert ranking for the roll forward in comparison to the cartwheel.

DISCUSSION

Research focusing on the storage of information in long-term memory provides evidence that mental representations control human actions (Hommel, 1996). Additionally, studies show a relation between mental representations and factors that might be influencing performance evaluation, such as visual and motor experience (Heinen et al. 2012; Schack & Mechsner, 2006). This is why the aim of this study was to analyze the relation between PE students' mental representation structure and their evaluation of pupils' skill performance, and thus, to answer the question, if the evaluation process is directly influenced by mental representations.

Results revealed that there is a relation between the mental representation structure and performance evaluation of PE students. In line with the hypothesis, the data indicate that the more similar the PE students' mental representation structure of the gymnastics skill compared to an experts' mental representation structure, the more similar the performance evaluation of this skill compared to an experts' performance evaluation. In other words, a better structured mental representation leads to a more precise performance evaluation.

First of all, these results indicate, that the structuring of mental representations is one important factor that influences the evaluation process of skill performance as it was assumed by the heuristic concept of Jeraj et al. (2015). Part of this process is the detection of errors, which is the result of an actual-target-comparison, the comparison between real and expected performances of the learner. The more structured the mental representation in long-term memory of the teacher, the better may be the actual-target-comparison, because the concept of how the expected performance of the learner should be like, may be clearer (Cloes, Hilert et al., 1995; Cloes, Premuzak et al., 1995; Jeraj, Hennig et al., 2015).

The results of this study complement findings of Pizerra (2012) and Heinen et al. (2012), since they report that motor and visual experience are influencing the judging process. Experts outperform novices in judging gymnastic skills – this can be traced back to their motor and visual experience but also (maybe on a superordinate level) to their mental representation structure of the motor skills. Furthermore, the result of Hoffman and Sembiante (1975), who suggested that teachers' performance evaluation is a function of skill familiarity, is supported by the results of the present study. A greater familiarity of an observer with a motor skill, the more structured the observer's mental representation structure of the skill and consequently, the observer's performance evaluation.

Focusing on the group of participants chosen in this study, it is important to consider that evaluation competency plays an essential role in PE. For example, central tasks of PE teachers are the provision of feedback, and the grading of pupils (Nicaise et al., 2006). In PE practice, it is essential to note that these tasks must be carried out in a short time frame. The results of this study indicate, that it might be possible to directly enhance teachers' performance evaluation by influencing and changing the mental representation structures in long-term memory of PE teachers. For example, through specific feedback or instructions developed based on the given structures or mental training programs combined with physical practice. Frank et al. (2016) showed improvements in motor performance and mental representation structures after mental and physical practice. Therefore, it should be considered to implement obligatory physical and mental training in the gymnastics training for future PE teachers.

Regarding the two skills cartwheel and roll forward, it was hypothesized that there is a task-specific difference. Following Hennig et al. (2016), the results suggest a specific role of the task to be assessed. Even though the number of criteria for the cartwheel and the roll forward were identical, it seems to be easier for the PE students to evaluate the roll forward. Different difficulty levels of motor skills might not only structure the mental representation but also affect observer's performance evaluation. The more structured the mental representation in long-term memory of the observer, the better may be the actual-target-comparison and this in turn might relate to task difficulty. The comparison between real and expected performances of the learner might be easier for an easy task.

There are limitations of this study and three specific aspects should be highlighted. First, it would be important not only to investigate mental representation structures of students but also of, for example, teachers with teaching experience of several years or even several decades. Groups of participants with different teaching experience could be compared, and the surveillance of the development of mental representations during a teachers' career could be interesting to focus on. By extending the selection criteria (e.g., concerning experience, age, area of work) for the group of participants, it may be possible to transfer the results to further groups, whose task is to evaluate motor performance, such as judges, coaches, commentators, and pupils. Referring to the first and second step of performance evaluation, observation and perception of the movement, not only different levels of experience should be taken into consideration but also factors that are hard to control like differences in perceptional or observational strategies. Second, two gymnastics skills were selected in this study to exemplify a more complex and a more basic floor exercise in gymnastics. For the purpose of this study the task selection was appropriate because of the defined evaluation criteria for gymnastic skills. But both skills can be categorized as closed skills. However, further research could focus on open skills with different demands, such as those skills that are performed in an unstable and dynamic environment (Gentile, 1972). Third, it could of course be possible to apply a more differentiated form of performance evaluation criteria, for example a grading of high, medium or low quality of the execution, as well as a different form of assessing mental representations (i.e., reaction times; Eysenck & Keane, 2000).

With regard to future research, it would be interesting to take a closer look at the relation between the mental representation structures of PE teachers and their pupils. An interesting question could be whether the development of learners' mental representations is influenced by their teacher's mental representation structure. This could help to provide insights into the communication between teachers and learners and possible ensuing difficulties.

CONCLUSION

It can be concluded that pre-service PE teachers use their mental representations of a motor skill, not only for their own motor performance but also as a basis for the evaluation of skill performance. Therefore, the acquisition of mental representation structures can be seen as important and useful for improving PE teacher training as well as training for professional observers in sports in general.

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THE FUNCTIONAL STABILITY OF THE UPPER LIMBS IN HEALTHY AND ROUNDED SHOULDER GYMNASTS

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Original article

Abstract

We aimed to assess and compare functional stability of the upper limbs in healthy and rounded shoulder gymnasts. A total of 30 male gymnasts aged 9-12 were selected according to the study inclusion and exclusion criteria and were assigned into a healthy and a rounded-shoulder group. The Upper Quarter Y-balance test was used to assess the functional stability of the upper limbs on the dominant and non-dominant sides. The paired t-test was used to compare the dominant and non-dominant arms and the independent t-test to compare the results between the two groups. The results obtained showed no significant differences in the functional stability of the upper limbs between the dominant and non-dominant sides. Furthermore, the functional stability of the upper limbs was found to be significantly higher in the healthy group compared to the rounded-shoulder group. It can be concluded that having rounded shoulders can significantly affect the YBT-UQ scores obtained and increase the risk of future injuries by reducing the functional stability of the upper limbs in closed kinetic chains. Rounded-shoulders should therefore be further addressed and efforts should be made to correct this problem in gymnasts so as to reduce their risk of developing upper limb injuries.

***Keywords**: Functional stability, upper limb, rounded shoulders, gymnastics.*

INTRODUCTION

The popularity of gymnastics has significantly increased among people in recent years and has led to a substantial increase in the number of people active this field, which may be due to the emphasis on women's exercise, the great talents in this field, the outstanding performances of some athletes and the inherent attractiveness of gymnastics(Sands, 2000). Following the increase in its popularity in different countries, the age of entry into gymnastics has decreased dramatically; for elite gymnasts to achieve sufficient competence, they need to begin their practices from age six to nine in order to get to its peak and raise the degree of difficulty of the movements at age ten (Caine & Maffulli, 2005). Another important change in gymnastics in recent years is the increasing complexity and the wide range of skills developed in this field, which in turn have led to changes in its movements. For instance, changes in the design of equipment, such as spring flooring, has caused changes in a variety of movements, and the increase in the number of rotations and spins and the increasing range of movement have made the field more difficult and increased the risks associated with these skills (Caine & Maffulli, 2005). Given the increasing popularity of gymnastics and the lower age of entry into the field and the start of training before the growth period, and also given the greater difficulty and complexity of gymnastics skills in recent years, concerns about the degree and severity of injuries in this field are well justified(Caine et al., 2008). Attention to upper limb injuries is particularly important in gymnastics, because, unlike in other fields, the upper limbs are extensively used for weight-bearing and dynamic closed chain exercises in gymnastics, which makes this part of the body the second most common part for gymnastics injuries(Webb and Rettig, 2008). According to studies, upper limb injuries may be responsible for more than half of the injuries caused by gymnastics; in one study, Dixon et al. (1993) reported that about 54% of injuries in elite gymnasts develop in the upper limbs (Dixon & Fricker, 1993).

The results of studies on the physical causes and risk factors of injuries in gymnasts suggest that injured gymnasts are larger in physical size (i.e. height and weight) and also have a greater body fat percentage compared to healthy and less-injured gymnasts (Lindner & Caine, 1993; Steele & White, 1986). The growth spurt age also contributes significantly to the risk of injury (Caine & Lindner, 1985; Micheli, 1983); in one study, Difiori et al. (2002) reported that 10 to 14 year-old gymnasts are significantly more likely to develop upper limb injuries compared to those outside this age range (DiFiori et al., 2002). A previous history of injury also contributes significantly to the risk of injury in elite gymnasts. About 30% of all injuries occurred in gymnastics have the potential to happen again (Caine et al., 2003).

Despite the numerous reports on upper limb injuries in gymnasts and the risk factors of injury in this part of the body, the role of musculoskeletal abnormalities in the incidence of these injuries has not yet been studied. Any deviation from the normal state of the body can adversely affect people’s performance and movement efficacy by changing the direction of the transfer of force and thus expose them to physical injuries by making them change the movement strategies they use (Desai et al., 2007).

Rounded shoulders comprise one of the most common musculoskeletal abnormalities that affect normal postural alignment in the upper limbs, making it deviate from its standard position (Peterson et al., 1997). This abnormality has been described as the protraction and elevation of the scapula and the forward positioning of the shoulders that makes the chest appear caved (Kendall et al., 1983; Kendall et al., 1970; Oyama, 2006). Researchers differentiate between rounded shoulders as an abnormality and kyphosis or excessive curvature of the spine; Kendall et al. (1970) showed that rounded shoulders occur on the horizontal plane while kyphosis occurs on the vertical plane (Kendall et al., 1970). Moreover, in rounded shoulders, the scapula are distanced, potentially resulting in winged scapula or the internal rotation of the humerus bones. Rounded shoulders cause changes in the static position of the scapula on the horizontal plane and may also cause the retraction of this muscle and subsequently the lengthening or attenuation of the rhomboid muscles by approximating pectoralis minor muscle heads to the coracoid process and 3rd, 4th and 5th ribs (Kluemper et al., 2006; Lynch et al., 2010). A reduction in the relaxation length of the pectoralis minor muscle can increase passive tension in this muscle when moving the arms, thereby limiting normal upward rotation, posterior slide and the outward rotation of the scapula (Borstad, 2006). Considering the changes that can occur in the pectoral girdle function due to rounded shoulders, this condition needs to be further addressed, especially among gymnasts compared to the general public, since the upper limbs are extensively used in gymnastics for weight bearing and closed kinetic chain activities, and thus any deformity in the pectoral girdle may increase the likelihood of injury in gymnasts by changing the physical function of the upper limbs (Webb and Rettig, 2008).

Of the tests designed to assess the performance of the upper limbs, very few evaluate the performance and dynamic stability of this region in closed kinetic chain activities (Falsone et al., 2002; Gorman et al., 2012; Jared Kitamura & Waitsc, 2007; Westrick et al., 2012). The Y-Balance Test-Upper Quarter (YBT-UQ) is a field test that assesses the unilateral dynamic performance of the upper limbs in a closed kinetic chain in conditions where stability is required during movement (similar to the conditions presenting in gymnastics) with minimum equipment (Gorman et al., 2012; Westrick et al., 2012). This test quantitatively assesses the functional stability of the subject when bearing his weight on only one hand in a three-point plank position and reaching maximum distance from the supporting hand in the medial, lower-side and upper-side directions (Butler et al., 2014). This test involves simultaneous central and shoulder stability and requires balance, neuromuscular control, proprioception, power and an extensive range of movement and is considered an efficient method for learning about performance, power and motor deficit in the shoulder (Butler et al., 2014; Gorman et al., 2012; Westrick et al., 2012). It thus appears that using this functional test can adequately predict the likelihood of injury in closed chain activities. Given the lack of studies on the effect of postural abnormalities on upper limb performance and the functional stability of the shoulders in closed chain activities, the present study was conducted to answer the question of whether or not rounded shoulders can affect the motor performance of the upper limbs in gymnasts in closed chain movements.

METHODS

The present causal comparative study was conducted to assess and compare the functional stability of the shoulder joint in a healthy group of gymnasts and another group with rounded shoulders. The study population consisted of 60 male gymnasts aged 9 to 12 who had regularly played gymnastics three days per week for the last three years. Participants' health status was determined prior to entering the study according to the General Health Questionnaire and written consents were obtained from them after they were briefed on the study objectives and methods. Ethical approval for this study has been granted by the Ethics Committee of the Lorestan University of Medical Sciences. Based on previous studies (Zandi et al., 2016), a total of 30 gymnasts were selected and placed in a healthy group (n=15) and a group with rounded shoulders (n=15). Participants with a history of head, spinal cord or upper limb fracture or surgery, those with 25<BMI<20 and those with a history of general joint hyperlaxity, neck osteoarthritis or pain in the neck and back were excluded from the study (Zandi et al., 2016).

The initial screening of the participants was performed using the New York physical examination with a chart screen (McRoberts et al., 2013) and 15 subjects with normal shoulders were randomly placed in the healthy group and 15 subjects with rounded shoulders were also randomly placed in the rounded-shoulder group.

The participants with rounded shoulders were quantified using a method consisting of percutaneous marking, digital photography (using Sony Cybershot DSC-WX200 camera) and AutoCAD 2014 (Aali et al., 2013; Raine & Twomey, 1994). In one study, Raine et al. (1994) reported a high validity and reliability for this method in the assessment of rounded shoulders (ICC=0.91)(Raine & Twomey, 1994). For this assessment, all the participants were first asked to remove their upper clothing and stand in front of the examiner. The seventh cervical vertebrae and the left and right acromion processes were marked as reference points, and in order to assume a normal position, the participants were asked to perform the military "at ease march" a number of times, rotate their shoulders forward and backward three times and then move their head backward and forward a few times (Najafi & Behpoor, 2012). Once the normal position was assumed, the examiner photographed the positioning of their head and shoulders in the sagittal view. This step was repeated three times, and in each repeat, participants' normal position was photographed, and the mean of the three angles obtained was ultimately recorded for each participant as the angle at which their shoulders were rounded. The photographs taken were uploaded into a computer and their different angles were assessed using AutoCAD. For this purpose, the angle between the horizontal line and the line passing through the seventh vertebrae and acromion process (Figure 1) was calculated and taken as the shoulder protrusion in degree(Aali et al., 2013; Raine and Twomey, 1994). All the measurements were taken at the same time (5-8 pm) by the same examiner.

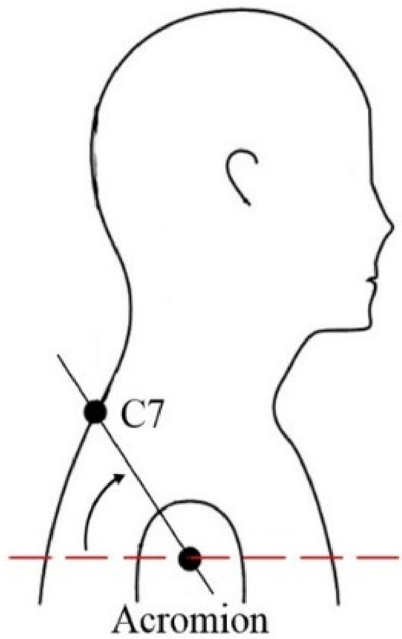

Figure 1. The photographic assessment of rounded shoulders.

The YBT-UQ was performed using special tools designed for the test, including a plane surface on which to place the supporting hand, and bars pointing at three directions in order to determine the reach in each direction. A movable cursor was placed on each bar to be slid by the free hand in order for the extension of reach in that particular direction to be measured (Zandi et al., 2016). To perform this test, the participant was asked to position the palm of his supporting hand so that the thumb and index finger were touching and the elbow was extended outward. In this stance, the toes had to be positioned as shown in Figure 2, and the spinal cord and lower limbs had to remain aligned. The position of the thumb was marked by a line and the feet were shoulder width apart. In this position, the participant was asked to reach as far as he could in the medial, lower-side and upper-side directions using his free hand while maintaining the position of his trunk, supporting hand and lower limbs (Figure 2).

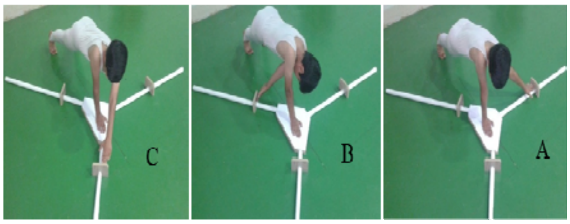

Figure 2. Reach in the medial (A), lower-side (B) and upper-side (C) directions.

The action of reaching was performed consecutively in all three directions without rest and without the free hand touching the ground, and after each round (i.e. a reach in all three directions), the participant was allowed to place his free hand on the ground and rest, and this process was to be repeated three times (Gorman et al., 2012; Zandi et al., 2016). The round had to be repeated if the participant removed his stationary hand from the plane surface or touched or leaned on the ground or cursor with his free hand and also if he was unable to return to the starting position with his free hand and lost his balance, or if one of his feet was lifted from the ground (Gorman et al., 2012). The participants were allowed to practice the move twice before performing the test.

To compare the participants, the extension of their reach was normalized using the length of their upper limbs (the distance between the seventh cervical vertebrae spinous process and the end of the longest finger at a 90-degree angle between the shoulder and the extended elbow, wrist and fingers). The highest extension of reach in each direction was eventually recorded (to the nearest 0.5 cm) and the overall combined score was calculated using the following equation (Cook, 2010; Zandi et al., 2016).

Combined score = (Medial reach + lower-side reach + upper-side reach)/(length of the upper limbs×3)

To compare the reach scores in the different directions, the scores were taken separately with the length of the upper limbs and the normalized reach score in each direction.

The collected data, including participants' details and the study variables, were analyzed in SPSS-20 using descriptive and inferential statistics. The Shapiro-Wilk test confirmed the normal distribution of the variables. The paired t-test was used to compare the results obtained about participants' dominant and non-dominant limbs, and the independent t-test was used to compare the results between the healthy group and the group with rounded shoulders ($P \leq 0.05$). The examiner first performed a pilot run of the tests on four subjects and then proceeded to performing the tests on the study participants once they had resolved all the problems.

RESULTS

Table 1 presents participants' demographic details by group. The independent t-test was used to determine the homogeneity of the groups in terms of the noted indices; however, no significant differences were observed between them and the groups were found to be matching ($P \geq 0.05$). The independent t-test was also used to compare participants in terms of their rounded-shoulder abnormality (Table 1).

Table 2 presents the results of the YBT-UQ for both the dominant and non-dominant limbs by group. According to the results, the highest reach was achieved in both groups in the medial, lower-side and upper-side directions and these values were slightly higher in the non-dominant compared to the dominant limbs.

The paired t-test was used to compare participants' dominant and non-dominant arms and the results showed no significant differences between the dominant and non-dominant arms in either group ($P \geq 0.05$); however, the independent t-test showed a significant difference between the two groups in the YBT-UQ results ($P \leq 0.05$). The results are presented in Tables 3 and 4.

Table 1
Participants' demographic details (mean ± SD).

Variable	Healthy group	Rounded-shoulder group	P Value
Age (year)	10/47±1/12	10/27±0/96	0/605
Height (cm)	137/60± 6/76	141/66± 9/15	0/178
Weight (kg)	41/53± 4/20	43/86± 6/05	0/231
BMI (kg/m^2)	21/90± 0/87	21/76± 1/01	0/700
Round-shoulder (degree)	75/33± 2/16	57/93± 1/79	0/001*

Table 2
The YBT-UQ results for upper limb length in percentage (mean ± SD).

	Healthy group		Rounded-shoulder group	
Direction	dominant arms	non-dominant arms	dominant arms	non-dominant arms
Medial	94/73±2/40	95/27±2/57	92/13±3/42	92/67±2/49
lower-side	85/07± 2/52	85/73± 3/73	82/80± 3/36	83/13± 3/09
upper-side	71/60± 3/29	72/13± 3/11	68/53± 4/05	69/07± 3/63
Combined	83/80± 2/52	84/37± 2/49	81/15± 3/54	81/62± 2/32

Table 3
A comparison of the balance scores obtained for the dominant and non-dominant arms using the paired t-test (mean ± SD).

	Direction	t	df	P Value
Healthy group	Medial	-1/331	14	0/205
	lower-side	-0/665	14	0/517
	upper-side	-0/816	14	0/428
	Combined	-1/136	14	0/275
Rounded-shoulder group	Medial	-0/900	14	0/383
	lower-side	-0/365	14	0/721
	upper-side	-0/913	14	0/377
	Combined	-0/847	14	0/411

Table 4
Comparison of the balance scores obtained for the healthy and rounded-shoulder groups using the independent t-test (mean ± SD.

	Direction	t	df	P Value
dominant arms	Medial	2/409	28	0/023*
	lower-side	2/089	28	0/046*
	upper-side	2/276	28	0/031*
	Combined	2/354	28	0/026*
non-dominant arms	Medial	2/806	28	0/009*
	lower-side	2/078	28	0/047*
	upper-side	2/482	28	0/019*
	Combined	3/129	28	0/004*

DISCUSSION

The present study was conducted to assess and compare the functional stability of the upper limbs between a healthy and a rounded-shoulder group of gymnasts using the YBT-UQ. The results showed that the highest reach scores obtained were in the medial direction in both groups, followed by the lower-side and the upper-side directions. These results are somewhat consistent with the results of previous studies; for instance, Westrick et al. (2012) reported the highest reach scores in the YBT-UQ in the medial, lower-side and upper-side directions (Westrick et al., 2012). In another study on the functional stability of the upper limbs in healthy volleyball players and those with anterior instability of the shoulder joint, Zandi et al. (2015) also reported the highest reach score in the medial direction in both groups, followed by the lower-side and upper-side directions (Zandi et al., 2016). Gorman et al. (2012) and Amasay et al. (2016) obtained similar findings (Amasay et al., 2016; Gorman et al., 2012). These findings can potentially be attributed to the positioning of the free hand in relation to the directions of reach when performing the test, since getting the highest reach score in the medial direction seems obvious, considering the position of the free hand in relation to the three directions and also given the lower-side and upper-side directions being in front of the free hand (Zandi et al., 2016). When reaching in the lower-side direction, the participants are somewhat able to boost their reach scores by rotating their body; in the upper-side direction, however, where the free hand is at a greater distance of the reach direction, the participant is unable to compensate for this distance using his body rotation and therefore gets lower reach scores in the upper-side direction compared to other directions (Zandi et al., 2016).

The findings also revealed higher reach scores for the non-dominant limbs compared to the dominant limbs in all three directions; however, Table 3 shows no significant differences between the reach scores obtained for the dominant and non-dominant limbs in the healthy and rounded-shoulder groups ($P \geq 0.05$). These results are consistent with the majority of previous findings on the functional stability of the dominant and non-dominant upper limbs (Butler et al., 2014; Gorman et al., 2012; Lite et al., 2013; Westrick et al., 2012). For instance, Westrick et al. (2012)

reported no significant differences between participants' YBT-UQ scores in the dominant and non-dominant limbs (Westrick et al., 2012). Gorman et al. (2012) also obtained similar results(Gorman et al., 2012). Nonetheless, some studies have reported disparate findings; for instance, Wilson et al. (2013) compared YBT-UQ results in water polo players and reported a significant difference between the reach scores obtained in the upper-side direction for the dominant and non-dominant limbs and attributed this difference to the stabilizing function of the non-dominant limbs in water polo players and argued that, since the supporting hand has a very similar role in the upper-side direction to the role of the non-dominant hand in stabilizing the body when passing and shooting in water polo, participants' are significantly more competent when performing the YBT-UQ using their non-dominant hand compared to the dominant hand in the upper-side direction, hence the significant difference between the reach scores of the limbs in the noted direction(Wilson et al., 2013). This stabilizing role is not observed in gymnastics movements and the dominant and non-dominant hands appear to be equally involved in gymnastics movements, which could be one of the reasons for the lack of a significant difference between the scores obtained for the different limbs in the present study. In another study, Zandi et al. (2015) also found a significant difference in the YBT-UQ scores between the dominant and non-dominant limbs (Zandi et al., 2016). The difference in the results between this and the present study can be explained by noting the difference in participants' characteristics; in Zandi's study, the participants had anterior instability of the shoulder joint in one of their limbs and it is only normal that this asymmetry in the characteristics of the limbs should cause a difference in the functional stability of the shoulders and thereby a difference between the reach scores obtained in the YBT-UQ (Zandi et al., 2016). In the present study, however, participants' dominant and non-dominant limbs were symmetrical. An inefficient sensory-motor system and the proprioception of the pectoral girdle are also likely to occur as a result of shoulder instability and can be considered another reason for the functional instability observed in the shoulders and the reduced reach scores obtained in the YBT-UQ in Zandi's study (Lephart et al., 1994; Myers et al., 2006). Overall, in line with the results of most studies discussed (Butler et al., 2014; Gorman et al., 2012; Lite et al., 2013; Westrick et al., 2012), the present findings also suggest that, despite the little evidence on the greater tendency to use the non-dominant limbs for creating functional stability, the difference observed is negligible and cannot cause a significant difference in the results of the YBT-UQ, in which the reach mainly takes place in the mid-range of the shoulder movement.

As for the effect of rounded shoulders on upper limb movement in closed kinetic chains, the present study showed that this abnormality can significantly affect the YBT-UQ results and reduce the extension of the reach in all three directions. Studies have reported that rounded shoulders associated with static scapular position in the horizontal plane can restrict normal upward rotation, posterior sliding and the outward rotation of the scapula by changing the length and tension of the muscles surrounding the shoulder joint when moving the arms (Borstad, 2006) and ultimately expose the individual to injuries in this part of the body by reducing the functional stability of the upper limbs. As discussed earlier, this issue is significantly more important in gymnasts, because, unlike other fields of sports, the upper limbs are used extensively for weight-bearing and closed chain movements in gymnastics, making this part of the body the second most-exposed to injuries(Webb and Rettig, 2008). Since no studies have yet examined the effect of musculoskeletal abnormalities on YBT-UQ results and given the present findings, these factors appear to also adversely affect the functional stability of the upper limbs and reduce the extension of the reach in the YBT-UQ just like in other physical injuries of the pectoral girdle. These results are somewhat consistent with previous reports; for instance, Hazar et al. (2014) reported that the reach scores obtained in the YBT-UQ are significantly higher in healthy people compared to those with shoulder impingement syndrome (Hazar et al., 2014). Zandi et al. studied the functional stability of the upper limbs in healthy volleyball players and those with anterior instability of the shoulder joint and reported significant differences in the reach scores obtained in all three directions between the two groups and also in their combined YBT-UQ scores (Zandi et al., 2016); the researchers argued that the anterior instability of the shoulder joint can reduce the integrity and increase the length of the joint capsule tissues and the rotator cuff muscle tendons and also cause dysfunction in the joint stabilizing elements and ultimately lead to mechanical instability in the shoulder joint by causing dysfunction in the arm rotation and tear in the rotator cuff muscle tendons (Myers et al., 2004). They also reported that, due to shoulder joint instability, the impairments caused in the function of the mechanical receptors of the joint inhibit the stabilizing neuromuscular reactions of the joint and lead to frequent injuries and progressive deterioration of the joint by disrupting the proprioception system (Lephart et al., 1994; Myers et al., 2004; Myers et al., 2006). Given the present findings, musculoskeletal abnormalities of the shoulder joint appear to be associated with a reduced proprioceptive accuracy and changes in the direction of the transfer of force(Ha et al., 2011). These problems can adversely affect motor performance and efficacy and expose the individual to physical injuries by changing their motor strategies. Studies have reported that any change in the alignment of the scapular bone can lead to disruption in the feedback from the muscle spindle receptors and also change the motor patterns that should act according to precise feedback from the proprioceptive receptors by causing dysfunction in the joint afferents. In these conditions, the muscle patterns are unable to harmoniously control muscle contractions and the joint thus develops functional instability (Ha et al., 2011). Given the changes that can occur in the pectoral girdle due to rounded shoulders, this deformity should be further emphasized, especially among gymnasts. Upper limb abnormalities, especially rounded shoulders, should be studied among gymnasts in order to prevent future injuries, and sports planners and trainers should seek to give corrective exercises to gymnasts for improving the abnormalities identified in this part of the body.

CONCLUSION

Rounded shoulders can significantly affect gymnasts' YBT-UQ scores and expose them to future injuries by reducing the functional stability of their upper limbs in closed kinetic chains. Considering that rounded shoulders are known as one of the most common musculoskeletal abnormalities that affect normal posture in the upper limbs (Peterson et al., 1997), and since the upper limbs are used extensively in gymnastics for performing closed chain movements, this condition should be more addressed in gymnasts and efforts should be made to correct it in order to help reduce upper limb injuries in this group.

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GENDER DIFFERENCES OF HIGH LEVEL GYMNASTS ON POSTURAL STABILITY: THE EFFECT OF ANKLE SPRAIN INJURIES

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Original article

Abstract

Artistic gymnastics is the sport with the highest number of injuries for the athletes involved. Several studies supported that the ankle and knee joints are the most commonly injured body parts of gymnasts. Ankle instability in particular is often caused by damage to passive structures leading to neuromuscular impairment. The purpose of this study was to assess gender differences on postural stability of high level gymnasts, with the effect of lateral ankle sprains injuries partially out. Ten high level female and 10 high level male gymnasts who experienced lateral ankle sprains injuries volunteered to participate in the study. Participants were assessed for postural stability on the NeuroCom EquiTest Computerized Dynamic Posturography system. Three tests were used to evaluate the: a) Unilateral Stance, b) Motor Control Test, and c) Adaptation Test. The scores for Unilateral Stance, Motor Control, and Adaptation tests were recorded. Significant gender differences were found on Unilateral Stance-Right Foot Eyes closed in slow velocity, on Motor Control Test for Amplitude Scaling on Left and Right Foot in Backward direction, and on Adaptation Test Toes down balance. Conclusively, female athletes exhibited better balance scores compared to males, when controlling for the number of lateral ankle sprains injuries they experienced during the last two years. These findings are discussed with respect to the severity of previous lateral ankle sprains injuries, and the experience from training and competing in different events, for males and females respectively.

***Keywords**: balance, ankle joints, gymnastics.*

INTRODUCTION

Artistic gymnastics (AG) is a sport that requires a great sense of body awareness (Robertson & Elliott, 1996). During training and competition, even small distribution in postural stability may adversely affect performance (Vuillerme et al., 2001). According to Hootman et al. (2007) AG is the sport with the highest number of injuries for the athletes involved. Several studies supported that the ankle and knee joints are the most commonly injured body parts of gymnasts (Tenvergert et al., 1992). When the passive structures are damaged (capsular structure and ligaments), they usually result in either objective (anterior drawer, talar tilt) and/ or subjective (giving-way) instability (Hootman et al., 2007). Neuromuscular impairments, in turn, incorporate decrements in dynamic balance (Sawkins et al., 2007) and postural control respectively (Liaw et al., 2008; Hrysommalis, 2007; Uchiyama & Demura, 2009).

According to Hutchison and Ireland (1995), the ankle sprains experienced often lead to chronic pain, swelling, and an increase in the postural sway (Jaussen, 2012). As previous studies have showed, ankle sprains associated with reoccurrence of injury (Holmes & Delahunt, 2009), that may result in damage to proprioceptors (Hertel et al., 2006; Sawkins et al., 2007), often result in instability of the joint and decrements in performance (Holder-Powell & Rutherford, 1999; 2000). According to Peterka (2002), in order to maintain an upright stance, the destabilizing torque due to gravity must be countered by a corrective torque exerted by the feet against the support surface. This correction is achieved by feedback mechanisms that generate an appropriate corrective torque based on body-sway motion detected by the visual, vestibular, and proprioceptive sensory systems. However, the primary source of information is provided by the visual system (Uchiyama & Demura, 2009; Winter et al., 1990).

Gender differences in postural stability, were recorded in the past for participants who were tested with their eyes either opened or closed. The limited research findings were conflicting, leaving this area open for future research (Blaszczyk et al., 2014; Kim et al., 2012; Lamoth et al., 2009). Concerning the reported number of injuries, Kobayashi and Gamada (2014) and Hootman et al (2007) found that gymnasts had higher injury rates compared to athletes in baseball, softball, e.t.c. The findings of Hootman et al (2007) are promising, since they summarize data collected from a national survey for a long period of 16 years, from 15 different sports in the USA. Overall, previous studies have shown that a decrement in balance can result from musculoskeletal injuries (Malliou et al., 2004), while the effect of vision is not confirmed (Blaszczyk et al, 2014; Kim et al., 2012; Lamoth et al, 2009). With respect to gymnasts, gender differences are conflicting, since one study reported higher balance scores for females (Milosis & Siatras, 2012), while the other study reported no gender differences (Davlin, 2004). With regard to the musculoskeletal injuries causing balance deficits, previous findings are evident in both the dynamic (Jibi & Nagarajan, 2014) and the static (Majlesi & Azadian, 2014) form, when the injured lower limbs of athletes from different sports were compared to the uninjured. In a recent study (Dallas & Dallas, 2016) investigated the effect of ankle sprain injuries on postural stability measuring the Limits of Stability (LOS) variables and found that females gymnasts recorded significantly lower values in Reaction Time and higher values in Movement Velocity during LOS test. However, it has not been reported whether: a) the number of these lateral ankle sprains injuries (LASI) influenced the gymnast’s postural stability and b) gender differences would still be evident, regardless the number of LASI experienced by the athletes. The Computerized Dynamic Posturography provides researchers with an objective mean to evaluate the postural components of balance, by assessing the postural sway velocity of either leg, with or without vision (eyes open and closed). The purpose of the present study therefore was to examine gender differences in dynamic and static postural stability of high level artistic gymnasts, who have suffered LASI in the past. The number of injuries served as a covariate. It is hypothesized that LASI affect gymnast's postural control and the number of these injuries may have an additional influence on postural control. However, if there is no gender differences it is speculated that other factor such as the training may have a positive effect on this ability. Based on previous research findings (Milosis & Siatras, 2012), it was hypothesized that female gymnasts would be more stable than their male counterparts, when the lower limb number of injuries was controlled. Further, following Winter et al (1990), it was anticipated that females would exhibit higher balance scores, compared to males, when vision was eliminated during balance testing.

METHODS

Ten female (age = 16.66 ± 3.20 years, mass = 47.30 ± 8.00 kg, height = 158.00 ± 5.7503 cm) and ten male gymnasts (age = 22.30 ± 1.77 years, mass = 62.00 ± 3.33 kg, height = 168.50 ± 3.03 cm) volunteered to participate in this single visit study. They had at least 10 to 15 years of training experience, training 6 days per week (25 – 30 hours per week), 3 to 5 hours daily**.** The primary researcher interviewed the coaches and participants who reported a) the total number of LASI (M = 2.00 ± 1.03, Females = 1.50 ± 0.34, Males = 2.50 ± 0.71), b) time before (months) the last LASI (M = 11.20 ± 2.65, Females =11.40 ± 2.80, Males = 11.00 ± 2.62), c) absence from training due to ankle injury and d) previous injuries in the lower limbs. The research took place during gymnasts' competitive period for national championships. Gymnasts were measured approximately 18 hours after the last training in order to exclude the influence of fatigue (Lin et al, 2009). The athletes reported that they a) spent less than 5 days without training due to past LASI and b) had no experience from previous injuries in the lower limbs.

One hour prior to the experimental protocol, a familiarization session and anthropometric measurements were performed. Three different tests for a total duration of 2 - 5 minutes approximately, including brief resting sessions (US: 6 trials * 10 sec = 60 sec = 1 min; MCT: 6 trial * 1 sec = 6 sec; ADT: 10 trials * 3 sec = 30 sec) were performed by each participant. All testing sessions were conducted at the same time of day (13:00 to 16:00). The study was conducted in accordance to the ethical principles regarding human experiments set by the Declaration of Helsinki.

Postural Stability was examined using the EquiTest Computerized Dynamic Posturography system. The Computerized Dynamic Posturography (CDP) protocol includes the following tests: a) Unilateral Stance (US), b) Motor Control Test (MCT), and c) Adaptation Test (ADT). The US quantifies postural sway velocity (deg/sec) with gymnasts standing on either the right or left leg, with eyes open and with eyes closed. Gymnasts were trying to react as the supporting surface moved in three different velocities; slow, medium, fast. The test was assessed by the mean CoG Sway Velocity that displays CoG stability while the gymnast stood independently on each leg. The MCT assesses the ability of the automatic motor system to quickly recover following an unexpected external disturbance. This consisted of sequences of small, medium or large platform translations which were scaled to the subject's height, in forward and backward directions to elicit automatic postural responses. The transportation of the supporting surface occurred regularly, in the same order, to the participants.

MCT records latency responses, which is a measure of how long it takes to restore normal balance following an unexpected perturbation. The measured parameters are the a) Weight Symmetry (a scale around 100 indicates that both legs are rearing equal weight, more than 100 means the subject bears more weight on their right leg and less than 100 means more weight on the left leg), b) Latency that quantifies the time between stimulus onset and initiation of the subject's active response and c) Amplitude Scaling that quantifies the strength of motor responses for both legs and for the three translations sizes. The ADT assesses the gymnast's ability to minimize sway when exposed to surface irregularities and unexpected changes in support surface inclination (toes-up or toes-down). For each platform rotation trial, a sway energy score (SES) quantifies the magnitude of the force response required to overcome induced postural instability**.** A smaller SES represented the ability of the gymnasts to react more efficiently.

A MANCOVA was used to examine gender differences (independent variable) in the postural stability tests, while number of LASI served as a covariate. Univariate analyses were used for post hoc comparisons. The Unilateral Stance Right Foot with Eyes Closed (US RF EC), Motor Control Test for Amplitude Scaling on Left Foot in Backward direction (MCT AS LF B) and Motor Control Test for Amplitude Scaling on Right Foot in Backward direction (MCT AS RF B) were the dependent variables. Further, a 2 X 5 MANCOVA examined the interaction effect between gender and time (5 trials), with respect to the Adaptation Test Toes down (ADTTd) scores. The independent variables were gender and time (5 trials), and the dependent variable was the ADTTd scores. Univariate analyses and the t-parameter estimates were used to evaluate the interaction effect. The intraclass coefficient assessed the reliability of the ADTTd scores.

RESULTS

Female gymnasts exhibited significantly lower number of LASI than male gymnasts on the right ankle joint ($p = .042$), the left ankle joint ($p = .048$), and the sum of both legs ($p = .025$) (table 1). The formula of Grimm (1993) was used to estimate the appropriate sample size. The calculated effect size was based in the study of Torres et al (2014) with the ML scores of 20 active men ($M = 0.95 \pm 0.25$) and 20 women ($M = 0.77 \pm 0.22$). The power analysis revealed that for an effect size of 0.766, power of 0.80 and a 0.05 alpha level, a total sample of 14 participants would be required to detect significant differences between groups.

The MANCOVA for Unilateral Stance Right Foot with Eyes Closed (US RF EC) was significant (Wilks $\Lambda = .545$, $F = 4.166$, $p = .025$, $\eta^2 = .455$). The univariate post hoc analysis was significant for US RF EC in slow velocity ($F = 5.639$, $p = .030$, $\eta^2 = .249$). Examination of the adjusted balance mean score in US RF EC revealed that the group of female gymnasts scored lower from their male counterparts. The above findings with respect to the US RF EC scores and adjusted scores, for both female and male gymnasts may be found in table 1.

The MANCOVA on Motor Control Test for Amplitude Scaling on Left Foot in Backward direction (MCT AS LF B) was significant (Wilks $\Lambda = .515$, $F = 4.708$, $p = .016$, $\eta^2 = .485$). The univariate post hoc analysis was significant for MCT AS LF B in slow translation ($F = 12.884$, $p = .002$, $\eta^2 = .431$), in medium translation ($F= 13.597$, $p= .002$, $\eta^2= .444$) and in large translation ($F = 7.531$, $p = .014$, $\eta^2 = .307$). Examination of the adjusted balance means score MCT AS LF B revealed that the group of female gymnasts scored lower from their male counterparts. The above findings, with respect to the MCT AS LF B scores and adjusted scores, for both female and male gymnasts, may be found in table 2.

The MANCOVA on Motor Control Test for Amplitude Scaling on Right Foot in Backward direction (MCT AS RF B) was significant (Wilks $\Lambda = .230$, $F = 16.716$, $p = .001$, $\eta^2 =.770$). The univariate post hoc analysis was significant for MCT AS RF B in slow translation ($F = 37.199$, p

= .001, η^2 = .686), in medium translation (F = 41.558, p = .001, η^2 = .710) and in large translation (F = 16.320, p = .001, η^2 = .490). Examination of the adjusted balance mean score in MCT AS RF B revealed that the group of female gymnasts scored lower from their male counterparts. The above findings with respect to the MCT AS RF B scores and adjusted scores, for both female and male gymnasts, may be found in table 3.

Table 1

Means and adjusted means in Postural Stability (Unilateral Stance Right Foot with Eyes Closed - US RF EC) for female and male gymnasts (deg/sec).

	Female	Male	p
Number of injuries *	1.55 ± 0.34	2.50 ± 0.71	.025
Postural Stability (US RF EC) (deg/sec)			
Slow Velocity*	1.55 ± 0.29	2.16 ± 1.01	.030
Medium Velocity	1.48 ± 0.51	1.92 ± 1.02	N.S
Fast Velocity	1.66 ± 0.50	1.84 ± 0.82	N.S
Adjusted Slow Velocity*	1.41 ± 0.24	2.29 ± 0.24	.030
Adjusted Medium Velocity	1.37 ± 0.27	2.02 ± 0.27	N.S
Adjusted Fast Velocity	1.56 ± 0.23	1.94 ± 0.23	N.S

* Significant gender differences (p < 0 .05)

Table 2

Means and adjusted means score in Motor Control Test for Amplitude Scaling on Left Foot in Backward direction (MCT AS LFB) for female and male gymnasts. Motor Control Test Left Foot Backward direction (MCT AS LF B)

	Female	Male	p
Number of injuries	1.55 ± 0.34	2.50 ± 0.71	.025
Postural Stability (MCT AS LFB)			
Slow translation *	1.80 ± 0.79	3.80 ± 1.31	.002
Medium translation *	3.00 ± 1.41	6.80 ± 2.15	.002
Large translation *	4.00 ± 1.49	8.00 ± 3.09	.014
Adjusted Slow translation *	1.77 ± 0.38	3.83 ± 0.38	.002
Adjusted Medium translation *	3.13 ± 0.63	6.67 ± 0.63	.002
Adjusted Large translation *	4.27 ± 0.84	7.73 ± 0.84	.014

* Significant gender differences (p < 0 .05)

Table 3

Means and adjusted means score in Motor Control Test for Amplitude Scaling on Right Foot in Backward direction (MCT AS RF B) for female and male gymnasts.

	Female	Male	p
Number of injuries	1.55 ± 0.34	2.50 ± 0.71	.025
Postural Stability (MCT AS RF B)			
Slow translation *	1.70 ± 0.82	4.40 ± 0.97	.001
Medium translation *	2.60 ± 0.97	7.70 ± 1.83	.001
Large translation *	3.50 ± 1.35	9.50 ± 3.41	.001
Adjusted Slow translation *	1.61 ± 0.31	4.48 ± 0.31	.001
Adjusted Medium translation *	2.65 ± 0.51	7.65 ± 0.51	.001
Adjusted High translation *	3.77 ± 0.89	9.23 ± 0.89	.001

* Significant gender differences (p < 0 .05)

Table 4

Means and adjusted means in Adaptation Test toes down (ADTTd) for female and male gymnasts.

	Female	Male
	Sway energy score	
$ADTTd_1$ (F = .387, p = .542, η^2 = .022)	60.30 ± 12.22	63.80 ± 19.74
Adjusted balance	59.35 ± 5.74	64.75 ± 5.74
$ADTTd_2$ (F = .004, p = .949, η^2 = .000)	57.20 ± 12.91	56.50 ± 21.13
Adjusted balance	56.55 ± 6.14	57.15 ± 6.14
$ADTTd_3$ (F = .765, p = .394, η^2 = .043)	54.40 ± 8.03	49.20± 11.48
Adjusted balance	54.10 ± 3.48	49.50 ± 3.48
$ADTTd_4$ (F = 3.658, p = .073, η^2 = .177)	51.80 $\pm$ 8.52	65.60 + 24.40
Adjusted balance	49.63 ± 6.27	67.76 ± 6.27
$ADTTd_5$ (F = 2.242, p = .153, η^2 = .117)	51.40 ± 5.05	59.30 ± 17.52
Adjusted balance	50.28 ± 4.47	60.42 ± 4.47

The Intraclass Correlation Coefficient, for the Adaptation Test Toes down (ADTTd), was .924 for the whole sample, and .845 and .956 for females and males respectively. The 2 X 5 MANCOVA revealed a significant interaction effect (Wilks Λ = .358, F = 6.286, p = .004, η^2 = .642). No significant main effect was found for time (F = 1.498, p = .256, η^2 = .300) and gender (F = .674, p = .423, η^2 = .038). Post hoc univariate analysis revealed that the interaction was significant in the 4th trial (F = 14.401, p = .001, η^2 = .459). Examination of the t-parameter estimates revealed that the females exhibited higher ADTTd scores in the 3rd trial (t = .875, p = .394, η^2 = .043) (Mean Females = 54.40 $\pm$ 8.03) compared to males (Mean Males = 49.20 ± 11.49), while the differences were reversed in the 4th trial (t = -1.913, p = .073, η^2 = .177) since females (Mean Females = 51.80 ± 8.52) scored lower than their male counterparts (Mean Males = 65.60 ± 24.40). The balance (ADTTd) scores and adjusted balance scores, for both female and male gymnasts across the 5 trials may be found in table 4.

DISCUSSION

This was the first study examining gender differences on static and dynamic postural stability of high level artistic gymnasts, when controlling for the number of previous LASI. Female gymnasts showed better postural stability in a) Unilateral Stance for Right Foot with Eyes Closed (US RF EC) in slow velocity, b) Motor Control Test for Amplitude Scaling on both feet in backward direction (MCT AS B) and c) ADTTd in 4th trial. The results of the present study verify data of Ekdalh et al (1989), who found that females demonstrated better balance postures than males. According to Winter et al (1990), when the equilibrium perturbation is small and the support surface is firm, female gymnasts use more effectively postural adjustments controlled by ankle muscles and overall restoration of the Center of Mass (CoM) to a central position, compared to males (Winter et al., 1990). Further, the ability to maintain balance is dependent on visual cues, vestibular function, and somatosensory feedback from structures in the lower limb (Nashner, 1993). When visual sensory information is absent (Accornero et al., 1997), the sensorimotor control of upright balance is based on information from ankle proprioceptors, in combination with plantar mechanoreceptors. Previous injuries damage the somatosensory information transmitted from the ankle proprioceptors leading to decrements in postural stability. Even though, in the present study the number of previous LASI was controlled, males exhibited lower balance scores compared to females, leading to the speculation that it was the severity of these past injuries that may have caused higher somatosensory damage in males, reduced proprioception and overall decrements in postural stability compared to females.

The severity or chronic musculoskeletal injuries may also explain the gender differences in the Motor Control Test for Amplitude Scaling, in backward direction. Chronic musculoskeletal conditions impair postural control (McKeon & Hertel, 2008) and have been reported in the unstable ankle (Ryan, 1994). The musculo-tendinous changes around the ankle are leading to a reduction of proprioceptive information and may contribute to the deficient postural control mechanisms after injury. This argument is supported by previous studies which showed that ankle symptoms may remain one year after lateral ligament injury (Moller-Larsen et al., 1988). It appears that the joint tissue of male gymnasts in the present study may have exhibited chronic musculo-tendinous changes around the ankle which, in turn, may have led to loss of proprioceptive information and overall deficient postural control, compared to females. Although no significant differences were found on MCT Weight Symmetry, examination on Amplitude Scaling on Left and Right Foot in Backward direction (MCT AS LF B) revealed that females achieved better use of their automatic motor system and recovered quicker from an unexpected external disturbance. Simply stated, the surrounding joint tissue of male gymnasts may not have been as sufficient for an effective function compared to females. Possibly, the previous severity of musculoskeletal injuries in the ankle joint along with the contribution of foot mechanoreceptors and cutaneous sensation may have influenced balance control (Meyer et al., 2004). However, our findings opposed those of Peterka and Loughlin (2004) who reported that healthy adults reacted more effectively on unstable supporting surfaces. The differences with Peterka and Loughlin may be attributed to the: a) sample of healthy adults examined and b) in the case of unstable base of support, the fact that male gymnasts examined in the present study may not use as effectively as their female counterparts their visual inputs (Peterka & Loughlin, 2004). This argument partially supports the results of Vuillerme and colleagues who found that elite male gymnast are more able to use the remaining sensory modalities to compensate for the lack of vision in unstable postures compared to non-expert counterparts (Vuillerme et al., 2001). In addition, our results reinforce findings of Kochanowicz et al. (2017) who found that gymnastic training had influence in postural control of young and adult gymnasts and those of Gautier et al. (2008) who stated that experts in sports requiring fine perceptive-motor control develop a shorter sensory–motor delay. Further, the fact that females scored better than male's maybe attributed to the specificity of training. Female gymnasts, for example, who practice gymnastic exercises on the balance beam, perform much better in balance than others who do not force the "balance system" as much (Wilke, 2000). Based on this logic, female gymnasts maybe considered as experts compared to males that have no similar experiences. In contrast, male athletes compete in two events actively using their lower limbs (vaulting horse and floor exercises), compared to females who compete in three events respectively (vaulting horse, balance beam, and floor exercises). In other words, females are spending more training time using their lower limbs, especially on the balance beam which is an exclusive apparatus for females requiring extensive balance training and skill. The above speculation is explained by Hubbard who claimed that the muscle spindle itself has been recognized as one of the afferent nerves that are potentially modifiable through training (Hubbard, 2005). In this sense, the ability to stabilize body position is mandatory for the performance of motor skills and is dependent upon the grade of experience (Wilke, 2000).

Analysis of the present data support the hypothesis that female gymnasts would be more stable than their male counterparts, when the lower limb number of injuries was controlled and that females would exhibit higher balance scores, compared to males, when vision was eliminated during balance testing. The present study showed that artistic gymnasts were dependent on vision in their postural stability tests and that differences were found in dynamic postural stability, especially when unstable supporting surfaces were used. These findings seem to suggest that female artistic gymnasts were more stable than their male counterpart, possibly due that practicing on the balance beam which allows them to practice and specialize in anterior-posterior direction of postural control. This finding verifies the results of Vuillerme et al (2001) who supported that postural skill may be influenced by the sport itself. Certain limitations, do not allow generalization of the present findings without caution. First, previous knee injuries were not recorded in the present study. Second, the external focus of attention may be another factor that differentiates female and male gymnasts (McNevin & Wulf, 2002). Researchers have reported that boys are less attentive and more agitated during the postural stability tests (Steindl et al., 2006). Attention however was not recorded in the present study. Third, certain anthropometric variables affecting postural balance, such as vision (Alonso et al., 2012) were not examined. Fourth, balance related gender differences may be due to other factors, based on body somatotype, independently of body size; for example the fact that boys have larger body mass and moments of inertia (Lee & Lin, 2007). Finally, other intrinsic factors such as age, gender, phase of menstrual cycle, type and severity of previous injuries, inadequate rehabilitation of previous injuries, aerobic fitness, fatigue, limb girth, anatomic alignment, gait, and foot morphology may play a role in the number of injuries experienced and overall balance scores (Murphy et al., 2003). The above limitations are useful for researchers to consider and re-examine in the future.

Certain recommendations may stem from the present findings. Coaches, physicians, physiotherapists and other experts in the field may need to monitor the rehabilitation process following ankle sprains. Even when athletes return to practice, the damage to the joint tissue may not have fully recovered. Assessing certain variables, such as strength in the muscles surrounding the ankle joint, range of motion, etc may be a useful indicator for coaches to consider for their injured athletes. Since limitations in balance have a negative impact upon performance, coaches may also consider adding balance sessions within their practice routines. If (male) athletes perform better in balance, they may also improve their overall performance (e.g. during the landing phase). Finally, coaches may need to constantly monitor the injuries experienced in the lower limbs, record them in detail and allow gymnasts to enter full practice and competition only when they have experienced full recovery.

CONCLUSIONS

The present findings showed that female gymnasts exhibited better postural stability scores compared to males, when controlling for the number of previous LASI. Taking into account that these injuries were recorded from 7 to 17 months prior to data collection, it appears that they may affect postural control long after acute injury resolution. Besides the rehabilitation treatment that these athletes were exposed, the training requirements for both male and female athletes may also have had an impact upon postural stability. No funding was provided for the designing and implementation of the present study. There was no conflict of interest, with an individual or organization, for the designing and implementation of the present study.

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NEW WAY OF DETERMINING HORIZONTAL DISPLACEMENT IN COMPETITIVE TRAMPOLINING

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Original article

Abstract

The assessment criteria for competitive trampolining, which is primarily both a technical and a compositional form of sport, have been extended by the addition of some objectively measurable parameters in recent years. In addition to the degree of difficulty and the movement execution score, which is often perceived as subjective, the actual "time of flight" for the athlete was introduced as an objective (performance) criterion. Beyond this, it is proposed that, in the future, the athlete's position should be recorded during the routines in the form of a series of positional profiles and that this information should be introduced as a further scoring criterion for "horizontal displacement" in the next Olympic cycle. Using a self-developed measuring system for determining both parameters (time of flight and positioning), the resulting possibilities for controlling training and performance, as well as the options for further development of the competition system or the sport of trampolining itself are described here.

Keywords*: trampolining, position determination, force sensors, measurement system.*

INTRODUCTION

International Gymnastics Federation (FIG) develop judging within Code of Points within each Olympic Cycle. Changes in judging are prepared by Technical Committies of each sport discipline with aim to make judging more precise and fair. New technologies, which can upgrade judging, should have high degree of reliability and validity. In trampoling judges evaluate difficulty, performance and time of flight (ToF). Following the introduction of Tof as a new scoring criterion during the last Olympic cycle, various studies have demonstrated the problems inherent in obtaining accurate time measurements using the Time Measurement Device system (TMD; Acrosport Co. Ltd., 2010). A comparison of the performance of the TMD with that of a laser-based light curtain to measure the heights of jumps and ToF conducted by Eisele and colleagues (Eisele, et al., 2015) confirmed the results in terms of lack of accuracy of the measuring system used previously for determining the ToF (Ferger, et al., 2013). The alternative measuring device used by Eisele and colleagues, manufactured by Sick AG, to determine ToF is indeed both reactionless and contactless, and broaches the possibilities for position determination on the trampoline bed. This measuring device cannot, however, provide important and immediate feedback for training and competitive situations, because of its time-consuming calibration and evaluation procedures.

There are a few key requirements for a measurement and information system, which should be able to operate in competition and training. In view of the new regulations for points scoring assessments (Code of Points/COP) for the next Olympic cycle (2017 – 2020), position determination is increasingly gaining in importance (FIG, 2016). This results in various requirements of a measuring and information system for determining ToF and positioning for both individual and synchronized trampolining competitions.

In order to be able to focus on other sports- and scientific-related questions beyond ToF and position determination, a measurement and information system for competitive trampolining was developed in a joint co-operative project between Eurotramp Trampoline Kurt Hack GmbH and Wassing Messtechnik GmbH. As a first step, a list of requirements for the measurement and information system planned was drawn up, taking into account the areas of training data documentation, safety, incentive function, equipment documentation and the further development of the competition system:

• precise and accurate location determination on the equipment;

• precise and accurate ToF determination;

• simplicity of the system and software;

• uninterrupted, reactionless and contactless measurements;

• high temporal resolution;

• availability of the results in real time and for training data documentation purposes;

• sport-specific interpretation and/or visualisation of the measurements; and

• integration into the Fédération internationale de Gymnastique’s (FIG) completion and scoring system

The deduction for horizontal displacement (HD) in individual and synchronized trampolining is calculated from the landing positions on the bed. The subdivision of the bed into different zones, which are each associated with corresponding deductions, is the foundation for the scoring of horizontal displacement (Figure 1).

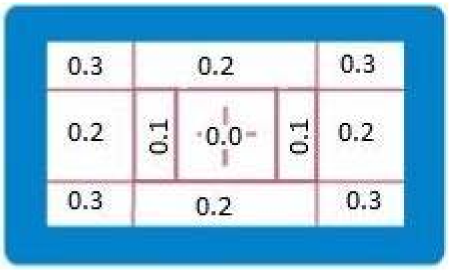

Figure 1. Deductions based on zones .

Judges need to determine the HD score visually in FIG competitions when there is no measurement system (FIG, 2016). Whether there is a difference in the deduction between a judge and the HD measurement system and whether the real landing position on the bed and, therefore, the right deduction is displayed with the HD measurement system need to be verified. A high-speed camera filming the trampoline at a vertical angle from the ceiling is a simple yet effective tool for determining the real zone in which the athlete lands. A recording with a high temporal resolution provides the ability to evaluate the deductions calculated by the HD measurement system. The aim of this study is to examine a possible application of the measurement system mentioned for horizontal displacement in competitive trampolining.

METHODS

The development of the measurement and information system, with technical details and system functionalities, is described in the following. The force sensors (Figure 2) (developed and constructed by Wassing Messtechnik GmbH) represent the technical core of the entire system. They use optoelectronic sensors and measure normal forces in a one-dimensional plane. The loads on the force platforms, which are positioned under the feet of the trampoline, produce a deformation of the metal plate or of the sensor and, thus, also a change in light intensity. Consequently, two voltages are measured, which are looped through the force plates via 8P8C modular connectors. The signal, containing 8 voltages, is broadcasted again through an 8P8C cable to the analogue to digital converter. After conversion, the digitalized signal is fed with a micro USB-to-USB cable into a windows-based laptop or computer (Figure 2). The overall cable length from force plate to laptop and, therefore, the distance between the trampoline and the judges, is tested up to 40 m. After taring the force plates under the feet of the trampoline, a custom C++ -based software visualises the single vertical forces applied on each force plate and the force summarized. The scanning is carried out effectively at 2 kHz (internally 50 kHz, mean average formation over 25 values). This means that current measurement values are available every 0.5 ms. The size of each of the force plates means that a resolution of better than 0.5 N is achieved at an accuracy of 1 %.

The basic principle is to measure the reaction forces on the trampoline at the set-up points (action = reaction), obtain the information desired by means of an appropriate evaluation and display this information. In addition to the development of a suitable sensor system for recording the static and dynamic forces occurring, the development of an evaluation device was promoted based on a systems theory analysis. The challenge was to analyse the raw data measured by the force sensors and to be able to separate the internal dynamics of the measuring apparatus from those of the athletes themselves. The resulting times of flight and positional data calculated can be simultaneously displayed in real time on the computer (Figure 3).

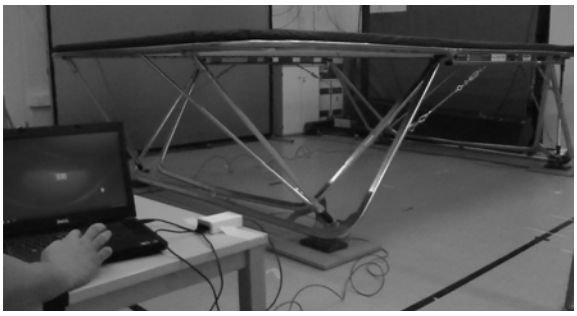

Figure 2. Force platforms under the trampoline connected to processing and output hardware.

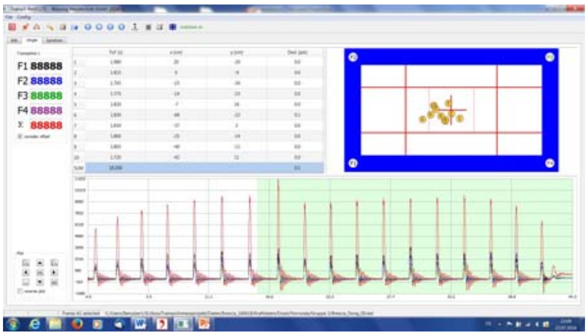

Figure 3. Screenshot – Sample display of results (Time of flights: ToF[s], positional profile based on the x and y co-ordinates measured; x/y [cm] with the corresponding deductions: Ded. [pts] and force curves).

It is both possible and essential to have a multiplicity of ways of displaying the results because of the many requirements of the system formulated in advance in both training and competition settings, and because of the differentiated reporting of the data to the various users (athletes, referees, competition judges, trainers and spectators). The measured values (ToF, position and force path profiles) are currently displayed in a tabular format, as force path curves and positional profiles. At the same time, these data are also recorded on a storage device (USB stick or SD card). The relevant data on jumps are animated in real time and the athlete can also be superimposed on this data stream by using an optional camera.

The first AERE World Cup in Brescia, Italy, (June17 – 19, 2016) was used as a test event for the system. The AERE World Cup was an official FIG competition and the measurement system was cleared for testing by the FIG Technical Committee. An international competition judge determined the deduction for horizontal displacement visually according to the landing of the athletes to evaluate the location determination. The competition judge was located in the upper area of the stands while the data were being obtained. From there, the cloth of both trampolines, including the zones, were completely visible. The deductions from 441 jumps from 25 male athletes were documented for a comparison between the judge and the system. All subjects were over 18 years of age. The jumps are, in both systems, divided into four categories: neutral zone, 0.1, 0.2 and 0.3 points deduction. If the deduction from the force plates and the visual deduction determined by the judge were the same, the jump was marked as a “match”. In case of a different deduction between the system and the judge, the jump was marked as a “no match”. With an expected error in the deduction due to the division of the cloth into zones, we set the maximal tolerable difference at 5 %.

Even though the competition judge is experienced and highly trained, a more precise and reliable measurement is necessary for a scientific view. Consequently, a comparison between the force plate system and a camera system took place in a Deutsche Olympische Sportbund training centre. A Basler acA1600-100 high-speed camera (Basler AG, Ahrensburg, Germany) with 100 Hz temporal resolution and 1600 x 1200 pixel video resolution was placed on the ceiling over a trampoline to record the exact landing position of the athlete. The camera was positioned at a ceiling height of 7.5 m aligned at a 90 ° angle to the bed, with the focus over the cross in the middle of the bed (Figure 1). Two male (17 and 20 years old) and two junior female athletes (10 years old each) performed ten routines each with a total number of 384 jumps. In addition to the permission of their coach and parents, all four participants were previously informed and gave their consent. The sample displays both ends of the weight range of usual participants in trampolining competitions: 32 kg for the female junior competitors and 67 and 68 kg for the male competitors. Using the position of the feet at the first contact with the bed in relation to the zones from high-speed video and the centre of pressure from the force plate system in relation to the zones, a comparison between the methods was made. The jumps are, in both systems, divided into four categories: neutral zone, 0.1, 0.2 and 0.3 points deduction. The results from both systems were compared for each jump and divided into the two groups (“match” and “no match”). Taking studies on artistic gymnastics into account (Čuk , 2015; Leskošek, et al., 2012; Pajek, et al., 2013) and with an expected error in the deduction due to the division of the cloth into zones, we set the maximal tolerable difference at 5 %. Chi-square provides a testing of proportion between expected and practical frequencies.

RESULTS

The 25 male athletes each performed two routines in the qualifying round at the AERE World Cup in Brescia. One routine consisted of 10 Jumps. Out of 500 possible Jumps, the athletes were able to perform 441. The missing jumps were due to forced stops, ranging from dangerous deductions to entirely missing the bed and injuries. The deduction estimated between the judge and the HD measurement system matched are represented in Table 1.

Table 1
Proportion of agreement between judges and force plate system.

	Technology yes	% from Total
Judges yes	425	96.4
Judges no	16	3.6
Total	441	100

The deduction in points of the two methods for the comparison with a high-speed camera was the same in 368 out of 384 jumps (95.83 %), and did not match in 16 jumps (4.17 %).

Table 2
Proportion of the comparison results over the sample. (S1 and S2 male, S3 and S4 female juniors).

Subject	Match	No Match	Sum
S1	93	3	96
S2	92	3	95
S3	95	2	97
S4	88	8	96
Sum	368	16	384

Table 2 shows the proportion of the comparison between the participants. The proportion of jumps in the categories "match" and "no match" do not differ significantly within the sample (χ^2 (3) = 5.75, $p < 0.05$). The proportions of the deduction categories were nearly the same (χ^2 (3) = 0.84, $p < 0.05$) for camera and the force plate system.

DISCUSSION

The benefits and possibilities for competitive trampolining with this system on hand are tremendous. Using the positions measured by the device together with the athletes' times of flight, it is possible, among other things and depending on the actual jump sequences, to create positional profiles and statements about spatial and temporal synchronicity.

Time of flight and position determination allow a systematic surveillance of individual jumps, jump sequences, and compulsory and voluntary routines during the training process. The recording and control of the interactions between the performance-related factors (ToF, bed contact time, distance travelled on the bed during the routine and/or during the individual jump sequences, force applied and the height of the jumps) additionally provide an opportunity to identify the athletes' deficiencies and reserve assets, and give valuable indications for (athletics) training which are appropriate for this specific type of sport (Lenk, et al., 2016; Lenk, et al., 2017). With an increased focus on position determination, together with the time recording for the ToF and/or bed contact times, it is possible to provide stimuli for jumping which are oriented around the body's centre of gravity and, thus, also improve the athletes' safety. In addition, the graphic representation of the data in real time offers the option of providing an "exciting" representation of the competition for the spectators.

These data can also be used retrospectively to obtain additional pointers for making improvements in equipment. The determination, for instance, of the state of the equipment (e.g. loss of elasticity) and the setting up of the equipment can be optimised on different types of surfaces (concrete, wooden and point elastic floors, competition stages and many more).

The observed percentage of disagreement between judge and system are neither an error of technology nor an error of judges. It is rather a problem of the different translation of the Code of Points. The judges are instructed to look for the athletes' feet during the bed contact. In the case if one foot is out of the neutral zone the judge indicate a deduction. In the same case the system detect the centre of mass inside the neutral zone and no deduction. These are the cases in which no agreement could be reached.

Obviously, further development of the competition system can be carried out. Only the ToF measurement of the TMD is currently used in both individual and synchronized competitions for determining measurements for the performance criterion ToF and for making the various deductions in the synchronized acrobatic moves. Different options are available for use in either the individual or the synchronized competitions.

For individual competitions, in addition to the determination of a movement profile over the distance covered, the subdivision of the bed into different zones, each associated with corresponding deductions (Figure 3), together with the total number of deviations from the midpoint, (Figure 4) represent other options for establishing a positional or an accuracy criterion. There is an issue in determining jumps on the lines which separate the different zones, especially considering the results of the comparison between the judge and the system. As a further development, the landing positions of the system should be evaluated with a more valid method, for example, using a kinematic camera system with markers on the athlete's feet.

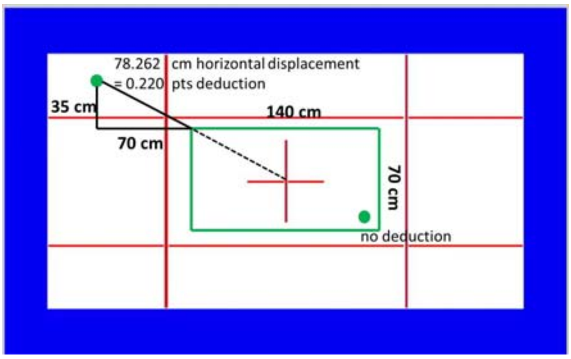

Figure 4. Deviations from the midpoint.

The determination of position in synchronized routines appears even more complex. Up to now, it has been possible to integrate an assessment of synchronicity into the score based solely on the time differences in landing. The new system broaches the possibility of being able to actually see and evaluate the synchronicity in a new way. The following aspects of synchronicity can now be observed in a more differentiated way: The synchronicity of the execution, which is reflected in the E-score, the time synchronicity in relation to the athletes landing on the equipment at the same time (ToF) and spatial synchronicity based on the athletes assuming the same landing positions.

In summary, performance-relevant factors which can be displayed in real time, such as ToF, contact with the bed, position on the bed, synchronicity and the forces and progressions which are produced, offer the possibility of providing competition judges with objective criteria for evaluating athletes' performances, and the athletes and their trainers with information for a more targeted management of their training and performance control, as well as making the competition more transparent and easier to follow for spectators and, thus, more enjoyable. In addition in the future, the setting up of the equipment can be optimised on different types of surfaces (concrete, wooden and point elastic floors, competition stages and many more), as can the determination of the state of the equipment (e.g. loss of elasticity).

There is also a great potential for the system in the field of training data documentation: individual positional profiles, flight times and time spent on the bed, as well as force progressions. It also offers the possibility of becoming the basis of a scientifically based and systematic method of controlling training and performance times. Furthermore, the subdivision of the definition of synchronicity into time, spatial and execution synchronicity shows that synchronicity cannot merely be assessed with reference to time differences in landing and, therefore, by the ToF. The solution currently being considered of making deductions in the various zones to form an HD score within the overall score, both in individual as well as in synchronized competitions, must certainly be discussed critically. This is because the problem in potentially uncertain cases where the line in a landing is clearly visible between the feet and the measuring system detects the body's centre of gravity on the line could be solved by the possibility described in terms of the deviation from the midpoint (c.f. Figure 4). In the end, the implementation of this system into the official competition system in a way which is acceptable to all parties remains a challenge.

CONCLUSION

New force plate system to measure gymnast's horizontal plane displacement in competitive trampolining showed high agreement with judges and with camera system. All evaluations were in agreement within error of less than 5 %. We could define new force plate system as valid and reliably.

New force plate system can be at this stage used at competitions to evaluate not only ToF, but also gymnast's horizontal plane displacement. When trampoline is fixed in gym hall it can be used also in training process. With whole data (ToF, HD), time of landing, time of take off, with added information about kind of jump, it can, therefore, be viewed as the first step in a long-term project of in-process training and competition research into competitive trampolining.

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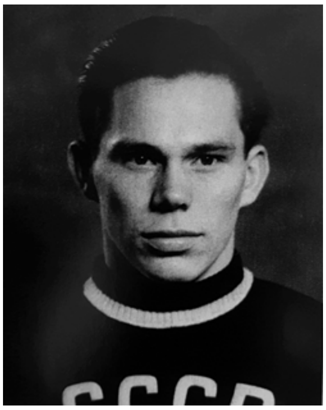
SHORT HISTORICAL NOTES X

Anton Gajdoš, Bratislava, Slovakia

Ph.D. Anton Gajdoš born on 1.6.1940 in Dubriniči (today Ukraine) lives most of his life in Bratislava (ex TCH, nowadays SVK). He comes from gymnastics family (his brother Pavel have world championship medals) and he devoted his life to gymnastics. His last achievement is establishment of Narodna encyklopedia športu Slovenska (www.sportency.sk). Among his passion is collecting photos and signatures of gymnasts. As we tend to forget old champions and important gymnasts, judges and coaches, we decided to publish part of his archive under title Short historical notes. All information on these pages is from Anton's archives and collected through years.

Jurij Jevlampijevič Titov (27. November 1935, Omsk, Russia)



Jurij Titov started his international career at Olympic Games in Melbourne in 1956. With team he won gold medal, in all around bronze medal, on horizontal bar bar silver and in vault bronze medal. Later he was attending also Olympic Games in Rome 1960 and Tokyo 1964. He ended his international career as gymnast after World Championship in Dortmund in 1966. During his 10 years long career he won 9 olympic medals (one gold with team 1956), 10 medals at World Championships (4 times World champion: with team, all around, vault and rings) and 14 medals at Europena Championships (8 times European champion: all around, 2 times on vault and rings, pommel horse, parallel bars, horizontal bar). After gymnastics career he started career as judge and gymnastics official. At the FIG congress he was elected as FIG president and his presidency was from 1976 up to 1996. During his presidency China started to compete at international competitions and rhythmic gymnastics became part of Olympic Games program. Later he was president and vice president of Russian Gymnastics federation.

His medals at international competitions:

Olympic Games
1956 Melbourne: Gold: team; Silver: horizontal bar; Bronze: all around, vault
1960 Rome: Silver: team, floor exercise, Bronze: all around
1964 Tokyo: Silver: team, horizontal bar

Figure left: from left Jurij Titov, Takashi Ono and Masao Takemoto – OG 1956 high bar. Jurij's the first international competition.

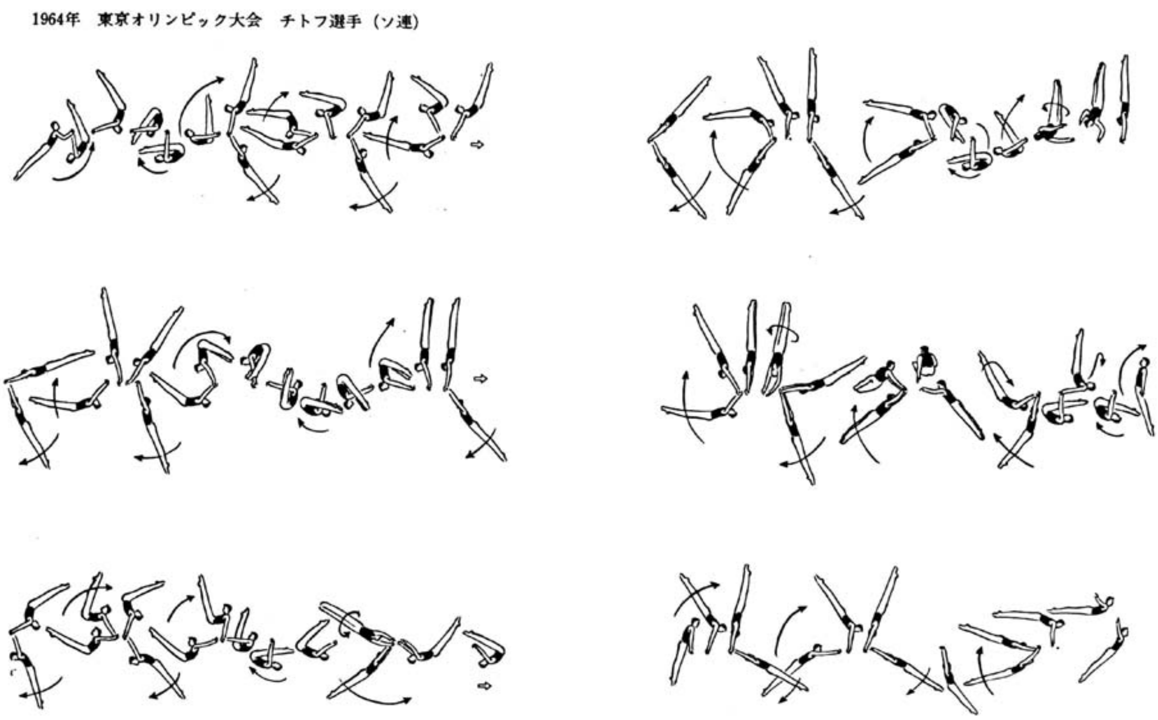
Figure bellow: from left J. Titov, V. Karasev, M. Voronin, B. Šahlin, S. Diomidov, V. Kerdemelidi, coach S. Litvinov. Jurij's the last international competition.

World Championship

1958 Moskva: Gold: team, vault, Bronze: all around, floor exercise, rings

1962 Praque: Gold: all around, rings, Silver: team

1966 Dortmund: Silver: team



Jurij Titov exercise on horizontal bar at OG 1964, (draw from Tadamiki Mori in Akitomo Kaneko (1970). Gymnastics Coaching Book II Horizontal Bar (Taisokyogi-Kyohon Tetsubo), FUMAIDO(Fumaido Shoten)) as it is in Anton's book of autographs.

European Championship

1957 Paris: Gold: vault, Silver: all around, rings, Bronze: horizontal bar

1959 Kopenhagen: Gold: all around, pommel horse, vault, rings parallel bars, Silver: horizontal bar, Bronze: floor exercise

1961 Luxemburg: Gold: rings, horizontal bar, Silver all around.

Passionate gymnasts during World Championship 2011. From left: Takashi Ono, Vera Časlavska, Abie Grossfeld and Jurij Titov (photo archive Abie Grossfeld)

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ПРЕЗИДЕНТ РОССИЙСКОЙ ФЕДЕРАЦИИ
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ПРЕЗИДЕНТ РОССИЙСКОЙ ФЕДЕРАЦИИ УВЕДОМЛЕНИЕ ТЕЛЕГРАФОМ МОСКВА НАБЕРЕЖНАЯ ЛУЖНЕЦКАЯ Д 8 ФЕДЕРАЦИЯ СПОРТИВНОЙ ГИМНАСТИКИ РОССИИ Ю Е ТИТОВУ=

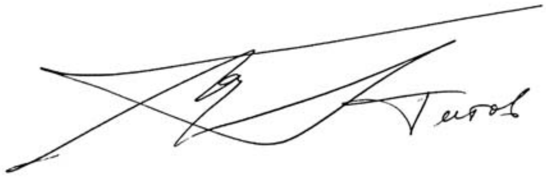
УВАЖАЕМЫЙ ЮРИЙ ЕВЛАМПИЕВИЧ
ПРИМИТЕ ПОЗДРАВЛЕНИЯ С 80-ЛЕТНИМ ЮБИЛЕЕМ.
УПОРСТВО И ВОЛЯ, ВЕРА В СОБСТВЕННЫЕ СИЛЫ И ИСКЛЮЧИТЕЛЬНОЕ ТРУДОЛЮБИЕ - ПОЗВОЛИЛИ ВАМ ДОБИТЬСЯ ВПЕЧАТЛЯЮЩИХ УСПЕХОВ В СПОРТИВНОЙ КАРЬЕРЕ, ЗАВОЕВАТЬ СОЛИДНОЕ КОЛИЧЕСТВО МЕДАЛЕЙ ВЫСШЕЙ ПРОБЫ, СТАТЬ ОЛИМПИЙСКИМ ЧЕМПИОНОМ.
И КОНЕЧНО, САМОГО ИСКРЕННЕГО УВАЖЕНИЯ ЗАСЛУЖИВАЕТ ВАША МНОГОЛЕТНЯЯ НАСТАВНИЧЕСКАЯ, ОРГАНИЗАТОРСКАЯ ДЕЯТЕЛЬНОСТЬ, ЗНАЧИМЫЙ ЛИЧНЫЙ ВКЛАД В УКРЕПЛЕНИЕ ПОБЕДНЫХ ТРАДИЦИЙ ОТЕЧЕСТВЕННОЙ ШКОЛЫ СПОРТИВНОЙ ГИМНАСТИКИ.
ЖЕЛАЮ ВАМ ЗДОРОВЬЯ, БОДРОСТИ ДУХА И ВСЕГО НАИЛУЧШЕГО.=
В. ПУТИН ПР-2368-

НННН Время-15:34 Дата-27.11.2015 Вх.номер-0042

Jurij Titov was for his work decorated with Olympic order by IOC in 1992, and important orders in Soviet union like Order of the Red Bannaer of Labour (twice, 1960 and 1980), Order of Friendship of Peoples (1976) and Order of the Badge of Honor (1957).

On the left telegraph from V. Putin, Russia president, wishen all the best for Jurij Titov 80th birthday.

Bellow Juri Titov signature.



Slovenski izvlečki / Slovene Abstracts

Andrej Kunčič, Jože Mešl

RAZVOJ TEKMOVALNIH REZULTATOV ALJAŽA PEGANA NA SVETOVNIH PRVENSTVIH

V članku je razčlenjenih 19 let – od 33 letne – tekmovalne kariere telovadca Aljaža Pegana. Njegove ocene, uvrstitve in sestave na drogu so predstavljene za vsako svetovno prvenstvo. Sestave so dodatno razčlenjene na posamezne prvine in njih opise. Predstavljene so v skladu s Pravilnikom za ocenjevanje Mednarodne telovadne zveze, ki so veljala za določeno štiriletno obdobje, in narejena je bila teoretična primerjava ob upoštevanju vseh sprememb in prilagoditev s Pravilnikom za ocenjevanje 2013 -2016. Poleg tega so prikazane razčlenitve sedmih Pravilnikov za ocenjevanje, ki so veljali v obdobju od 1989 do 2013. Prilagoditev spreminjajočim se kriterijem Pravilnika za ocenjevanje je mogoče videti v sestavah s prvinami, ki jih je Aljaž dodajal zaradi izjemnega znanja osnovnih gibanj na drogu, kot so vse vrste točev, letov in prvin v obrnjenem podprijemu. Med svojo kariero sta Aljaž in njegov trener izumila dve prvini, ki nosita njegov priimek v Pravilniku za ocenjevanje, Pegan na drogu in Pegan na bradlji. Njegov največji uspeh je bil na svetovnem prvenstvu leta 2005 v Melbournu v Avstraliji, kjer je postal svetovni prvak na drogu.

Ključne besede: moška tekmovalna orodna telovadba, drog, razvoj rezultatov, Pravilnik za ocenjevanje.

Almir Atiković, Sunčica Delaš Kalinski, Ivan Čuk

SPREMINJANJE STAROSTI UDELEŽENCEV PRI TEKMOVALNI ORODNI TELOVADBI OD LETA 2003 DO 2016 NA SVETOVNIH PRVENSTVIH IN OLIMPIJSKIH IGRAH

Cilj raziskave je bil ugotoviti spremembo starostne strukture telovadcev in telovadk na olimpijskih igrah in svetovnih prvenstvih od leta 2003 do leta 2016. Skupno število udeležencev v moški tekmovalni orodni telovadbi je bilo 2678 in pri ženskah 1981; medtem ko je bilo na olimpijskih igrah 391 telovadcev in 389 telovadk. V zadnjih 15 letih je bila ugotovljena linearna in polinomska regresija druge stopnje v starostni strukturi udeležencev na največjih svetovnih tekmovanjih. V razčlenjenem obdobju se je povečala starost telovadcev in telovadk. Telovadci so od leta 2003 do leta 2016 v povprečju starejši za 2,3 leta, telovadke pa za 3,3 leta. V prihajajočem obdobju pričakujemo (tudi zaradi dodatnih tekmovanj na posameznih orodjih), da se bo ta starost povečala.

Ključne besede: tekmovalna orodna telovadba, razvoj, moški, ženske.

Linda Hennig

POMEN VIDNE PREDSTAVE PRI OCENJEVANJU TELOVADNIH ZNANJ ŠTUDENTOV TELESNE VZGOJE

Raziskave dokazujejo, da duševne predstave nadzorujejo človekova dejanja. Ugotovljena je tudi povezava med duševnimi predstavami in dejavniki, ki vplivajo na oceno uspešnost. Vrednotenje gibalnih znanj je pomembno pri telesni vzgoji, saj je to osrednja naloga učiteljev, za zagotavljanje povratnih informacij in ocenjevanje. Namen te študije je bil torej preučiti razmerje med predstavami in ocenjevanjem telovadnega znanja učencev pri študentih telesne vzgoje.. Duševne predstavitve in ocene so bile ocenjene pri N = 30 PE študentov s pomočjo strukturne dimenzionalne analize – gibalnega in video testa. Mentalne predstavitve udeležencev in ocene uspešnosti so primerjali z referencami strokovnjakov. Rezultati so pokazali pomembne razlike v primerjavi ocen uspešnosti za skupino udeležencev z bolj strukturirano in skupino z manj strukturiranimi mentalnimi predstavitvami, kar kaže, da so bolj strukturirane miselne predstavitve povezane z bolj natančno oceno uspešnosti. Raziskava kaže, da obstaja razmerje med duševnimi predstavami študentov in njihovim vrednotenjem telovadnega znanja. Zato se predlaga, da se za usposabljanje bodočih pedagogov telesne vzgoje, izvaja obvezno telesno in duševno usposabljanje pri telovadbi.

Ključne besede: vrednotenje uspešnosti, SDA-M, roll naprej, kolovoz.

Ramin Beyranvand, Rahim Mirnasouri, Saeid Mollahoseini, Sadegh Mostofi

TRDNOST ZGORNJE OKONČINE PRI ZDRAVIH IN GRBASTIH TELOVADCIH

Cilj je bil oceniti in primerjati trdnost zgornjih okončin pri zdravih in grbastih telovadcih. V skladu z merili za vključitev in izključitev iz študije je bilo izbranih 30 telovadcev, starih od 9 do 12 let, in so bili razdeljeni v zdravo in grbasto skupino. Četrtni Y preiskus ravnotežja je bil uporabljen za oceno trdnosti zgornjih okončin na prevladujoči in ne prevladujoči strani. Parni-test je bil uporabljen za primerjavo prevladujočih in ne prevladujočih rok ter neodvisnega t-testa za primerjavo rezultatov med obema skupinama. Dobljeni rezultati niso pokazali pomembnih razlik v trdnost zgornjih okončin med prevladujočo in ne prevladujočo stranjo. Nadalje je bilo ugotovljeno, da je trdnost zgornjih okončin bistveno višja v zdravi skupini v primerjavi s skupino z grbo. Lahko sklepamo, da lahko grba znatno vpliva na dosežene rezultate in povečajo tveganje za prihodnje poškodbe z zmanjšanjem trdnosti zgornjih okončin v zaprtih kinetičnih verigah. Grbo je zato treba nadalje obravnavati in si je treba prizadevati, da se ta problem odpravi pri telovadcih, da se zmanjša tveganje za nastanek poškodb zgornjih okončin.

Ključne besede: trdnost, zgornja okončina, grba, telovadci.

George Dallas Alexandros Mavidis, Costas Dallas, Sotris Papouliakos

RAZLIKE MED TELOVADCI IN TELOVADKAMI NA DRŽO TELESA: VPLIV ZVINA GLEŽNJA

Tekmovalna orodna telovadba je šport z največjim številom poškodb glede na število športnikov. Številni študiji so potrdile, da sta gleženj in koleno najpogosteje poškodovana pri telovadbi. Nestabilnost gležnja je pogosto povzročena z nedejavnostjo živčno mišičnih struktur. Namen študije je bil oceniti razlike med spoloma na držo telesa visoko uspešnih telovadcev in telovadk z poškodbo zvina gležnja. Deset telovadcev in deset telovadk, ki so doživeli zvin gležnja, so se prostovoljno udeležili študije. Udeležencem smo ocenili držo telesa s napravo NeuroCom EquiTest Computerized Dynamic Posturography. Uporabljeni so bili trije testi: a) stoja na eni nogi, b) test nadzora gibanja in c) test prilagoditve. Razlike med spoloma so bile ugotovljene pri stoji na eni nogi – na desni nogi z zaprtimi očmi, pri nadzoru gibanja pri počasni hitrosti na levi in desni nogi v smeri nazaj, in na testu prilagoditve pri vzponu. Telovadke so pokazale boljše rezultate v primerjavi z moškimi, glede na število poškodb, ki so jih imeli v zadnjih dveh letih. Ob ugotovitvah je potrebno upoštevati resnost poškodbe zvina gležnja in različnost vadbe in tekmovanj za moške in ženske.

Ključne besede: ravnotežje, zvin, gleženj, gimnastika.

Katja Ferger and Michel Hackbarth

NOVI NAČIN UGOTAVLJANJA PREMIKANJA V VODORAVNI RAVNINI PRI TEKMOVANJIH NA VELIKI PROŽNI PONJAVI

Merila za ocenjevanje na veliki prožni ponjavi, sočasno upoštevajo težavnost in izvedbo, z novimi tehničnimi dosežki in nekaterimi objektivno merljivimi parametri pa so še izboljšali ocenjevanje v zadnjih letih. Poleg stopnje težavnosti in izvedbe gibanja, ki se pogosto dojemajo kot subjektivni, je bil dejanski čas leta za akrobate uveden kot objektivni (izvedbeni) kriterij. Poleg tega se predlaga, da bi se v prihodnosti položaj akrobata na ponjavi zabeležil med sestavami v obliki serije natančnih položajev in le-te podatke uvesti kot dodaten merilni rezultat za premikanje v vodoravni ravnini v naslednjem olimpijskem obdobju. Opisan je novo razviti merilni sistem za določitev obeh spremenljivk (čas letenja in sledenje položaja na ponjavi), ki bi se poleg ocenjevanja na tekmovanju, lahko uporabljal tudi za nadzor akrobata pri vadbi.

Ključne besede: velika prožna ponjava, določanje položaja, senzorji sile, merilni sistem.