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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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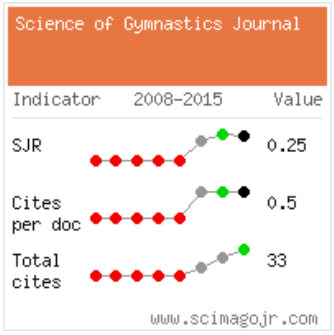

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CONTENTS

Dear colleagues, academics, researchers, coaches, gymnasts, judges, students, and all those involved with gymnastics, we are pleased to invite you to participate in the International Seminar on Competitive Artistic and Rhythmic Gymnastics (SIGARC) 2017, which thanks to previous experiences, with support of universities and partner institutions, is in its 5th Edition.

This event aims, through conferences, round tables, workshops, and exhibition of scientific works in poster format, to propose an environment for reflections and sharing of knowledge, innovation, technology, and experiences that enable the continuity process of competitive Gymnastics development in Brazil.

The SIGARC 2017 will be held at the Centre for Physical Education and Sports (CEFD) at the Federal University of Espírito Santo (UFES), in the city of Vitoria. This beautiful city in southeast of Brazil is homeland of gymnasts such Natalia Gaudio, Franciely Machado, and Emmanuele Lima that represented Brazil in rhythmic gymnastics at the 2016 Olympic Games. The city is also homeland of Monika Queiroz who coached Brazil in two Olympics editions (2008 and 2016).

The Mission of SIGARC is to create approaches among students, judges, coaches, gymnasts, researchers, and other professionals who work with gymnastics, creating an atmosphere where is possible to share experiences and knowledge benefiting each other. This is one of the paths to the growth and development of our gymnastics, in order to benefit everyone.

Visit website for more information: SIGARC 2017, https://sigarc2017.wixsite.com/ufes-en

EDITORIAL

Dear friends,

Competitions under FIG and Continental Unions flag this spring have already brought about new heights of development. Especially in artistic gymnastics we have been surprised by presentations of the triple salto backward tucked on floor and the triple salto backward piked from rings (which MTC FIG recognises as a new element with H difficulty and goes by the name of Donnel Whittenburg). We are proud that Whittenburg performed it in Slovenia, during the World Challenge Cup in Koper.

Not only gymnasts and coaches are searching for new content but also researchers world-wide. The first article in this issue comes from a group of researchers from Germany lead by Thomas Heinen. They looked at how the gymnast's motor control regulates Yurchenko vaults. The article includes some very important information for coaches in the sense of motor learning.

The second article is a review by Slovene authors Boštjan and Barbara Jakše (the latter used to be a gymnast who competed at World Championships under her maiden name Turšič) in which they discuss the importance of omega-3 fatty acids for gymnastics. A lot of condensed information again with high value not only for coaches but also gymnasts and their parents.

The third article is by one author only from Croatia. Sunčica Delaš Kalinski explored the main reasons why female artistic gymnasts rarely participate in more than one Olympic Games. Another article for coaches to think about their gymnasts' careers.

The fourth article is from a team from Greece lead by Maria Kritikou. It looks at the correlations between artistry performance scores and morphologic characteristics and motor abilities. The article provides lots of interesting information for coaches, judges and gymnasts in the area where artistry influences the final scores.

The fifth article comes from Portugal. An analysis of rhythmic routines by Amanda Batista, Rui Garganta and Lurde Avila Carvalho concludes that the more difficult elements result in lower scores as judges influence the evaluation of whether difficulty is recognised or not.

The sixth article is also from Portugal. Researchers around Maria-Raquel G. Silva analysed gender inequalities in the Portuguese gymnastics between 2012 and 2016. Perhaps the new FIG discipline, parkour, will help make gymnastics in Portugal more popular among males.

The last article comes from a mixed group researchers from the Czech Republic and Slovenia. The group, led by Karmen Šibanc, compared morphological characteristics of top level gymnasts between years 2000 and 2015. Two different philosophies of the Code of Points have also had a minor impact on the changing morphologic structure of gymnasts.

Anton Gajdoš prepared a new contribution on gymnastics history, refreshing our memory of German team at OG 1896, Walther Lehman and Yukio Endo.

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

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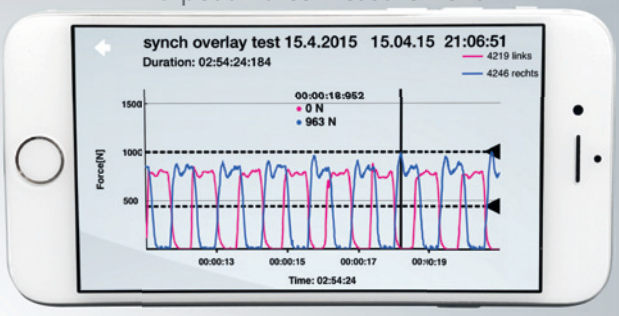

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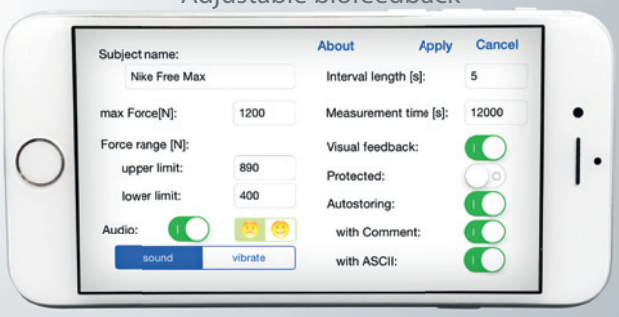

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THE ROLE OF POSITIONAL ENVIRONMENTAL CUES IN MOVEMENT REGULATION OF YURCHENKO VAULTS IN GYMNASTICS

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Original article

Abstract

Numerous gymnastics skills demand a precise interaction between the gymnast and the environment. It remains unclear, how different environmental cues act and interact in the regulation of complex skills, such as Yurchenko-type vaults, where the gymnast performs a round-off before contacting the springboard. The aim of this study was to assess the roles of both, the position of the round-off mat and the position of the springboard, in the regulation of a Yurchenko timer. Kinematic parameters of eight female expert gymnasts' Yurchenko timers were examined in a baseline condition and two experimental conditions with different manipulations of the positions of the round-off mat and the springboard. Results revealed that visually controlled regulation of the run-up occurred in average two steps prior to the hurdle. Hand positioning on the round-off mat preceded a constant round-off flight phase. Gymnasts placed their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. Finally, hand positioning on the vault block mainly varied as a function of the position of the springboard and the distance of the flight phase to support. This study provides evidence that the position of the springboard regulates Yurchenko-type vaults. Knowledge about relationships between informational sources in the environment and the resulting motor behaviour in gymnasts may help coaches to develop training programs aiming to enhance gymnasts' ability to utilize this information in skill performance under changing environmental conditions in training and competition.

Keywords: *visual perception, task demands, yurchenko timer, kinematic analysis.*

INTRODUCTION

Complex gymnastics skills such as a Yurchenko on vault demand a precise interaction between the gymnast and the environment (Bradshaw, 2004; Kwon, Fortney, & Shin, 1990). In particular, gymnasts need to precisely hit the springboard and the vaulting table, in order to successfully perform the intended vault (Arkaev & Suchilin, 2004; George, 2010). To do so, gymnasts require access to perceptual information about themselves and their environment (Raab, de Oliveira, & Heinen, 2009; Warren, 2006). Utilizing visual information of particular environmental cues is thought to be of high importance in movement regulation of complex skills (Bradshaw, 2004; Fajen, Riley, & Turvey, 2008; Gautier, Thouvarecq, & Chollet, 2007; Warren, 2006). Nevertheless, the question arises, how different environmental cues act in the regulation of complex skills in gymnastics.

Perception-Action Coupling in Complex Gymnastics Skills

When a gymnast moves, he/she picks up information from the environment. This information is processed by different perceptual systems in their specific mode of operation (Vickers, 2007). The visual system processes for instance light that is reflected from the surrounding environment, and visual information contains the invariant features of the environment that gymnasts may utilize in movement regulation (Davids, Button, & Bennett, 2008; Gibson, 1979; Latash, 2008). The strong advantage of the visual system is that it enables the gymnast to pick up *distal* information, such as the position and structure of objects in the surrounding environment (Land, 2006; von Laßberg, Beykirch, Mohler, & Bülthoff, 2014). A gymnast might use this information in terms of an anticipatory control strategy to time and regulate his/her current action (i.e., run-up) to future events and event-related effects (i.e., placement of feet on springboard) in order to achieve a particular movement goal (Bardy & Laurent, 1998; Bradshaw, 2004; Hoffmann, Stoecker, & Kunde, 2004; Lee, Young, & Rewt, 1992; Turvey, 1992; Warren, 2006).

Gymnasts develop task-specific long-term memory representations during skill acquisition (Rosenbaum, Cohen, Jax, Van der Wel, & Weiss, 2007; Schack, Essig, Frank, & Koester, 2014). These representations contain information about relationships between intended motor behaviour/s and associated perceptual effects with regard to a particular movement goal (Latash, 1993; O'Regan & Noë, 2001; Prinz, 1997; Rosenbaum et al., 2007; Schack et al., 2014). In skilled gymnasts, these representations are thought to facilitate information pick-up and processing, because gymnasts better know *when* to utilize *which* information (Gegenfurtner, Lehtinen, & Säljö, 2011; Schack & Ritter, 2009). This in turn supports skill performance because skilled gymnasts attend to perceptual information that can be used directly and relied upon in movement regulation in order to achieve a particular movement goal (Montagne, Cornus, Glize, Quaine, & Laurent, 2000; Raab et al., 2009; Renshaw, Davids, Chow, & Shuttleworth, 2009; Schack, 2003; Withagen & Michaels, 2005).

Given the outlined theoretical perspective one could speculate that information derived from the structure of the vaulting apparatus, such as the perceived position of the round-off mat and the springboard, are likely to guide action in gymnastics vaulting because they might afford a precise interaction in order to perform the intended vault. Skilled gymnasts should therefore directly utilize this information when regulating action (Bradshaw, 2004; Heinen, Vinken, Jeraj, & Velentzas, 2013). Empirical evidence supporting this argumentation is summarized in the following paragraphs.

Movement Regulation in Gymnastics Vaulting

Meeuwsen and Magill (1987) could show that gymnasts' running kinematics differed when comparing the run-up for a handspring on vault (in which the task was to precisely hit a springboard in order to perform a reactive leap) with sprinting when no vaulting apparatus was present. The authors assessed several kinematic measures, such as stride length and stride duration. In particular, accuracy of feet placement on the springboard was related to the consistency of the stride length during the final part of the run-up and the hurdle. It was argued that visual information was utilized in the final part of the run-up (and the hurdle), indicating the use of visual information when the vaulting apparatus was present and when the task was to hit the springboard in order to perform a handspring. The results support the notion that gymnasts might use current perceptual information in terms of an anticipatory control strategy to time and regulate current action (i.e., feet placement

during run-up) to future events (i.e., placement of feet on springboard) in order to perform an adequate handspring (i.e., Lee et al., 1992).

Bradshaw (2004) asked gymnasts to perform round-off entry vaults. Gymnasts' performances were videotaped and several kinematic parameters were analyzed from the videotaped performances. In particular, the onset of visual control was calculated from gymnasts' natural motor behaviour in the final part of the run-up. Results revealed that onset of visual control occurred in average two steps prior to the hurdle in Yurchenko-type vaults in gymnastics. In addition, the onset of visual control was related to parameters such as take-off velocity from the springboard, as well as post-flight distance of the vaults. This result highlights the functional role of visual information pickup during the run-up (and hurdle) for optimized skill performance in gymnastics vaulting (i.e., Raab et al., 2009).

Heinen, Jeraj, Thoeren, and Vinken (2011), as well as Heinen et al. (2013) asked gymnasts to perform handsprings on vault. The authors analyzed gymnasts' movement kinematics of the handspring vaults under different experimental conditions. In particular, the position of the springboard (Heinen et al., 2011), as well as the position of the springboard and/or the vaulting table (Heinen et al., 2013) were manipulated without gymnasts' awareness. Results revealed that a manipulation of the springboard position and the vaulting table position leads to predictable changes in movement kinematics during run-up (and other movement phases) of a handspring on vault. In the light of these findings one could argue that the (perceived) positions of the springboard and the vaulting table might be relevant informational cues when performing handsprings on vault (Heinen et al., 2011, 2013). The results support the notion that skilled gymnasts may attend to perceptual information that can be used directly and relied upon in movement regulation in order to achieve a particular movement goal (i.e., Withagen & Michaels, 2005).

Skilled gymnasts utilize visual information picked up from the environment in the regulation of complex skills. Empirical evidences support the notion that the positions of both, the springboard and the vaulting table seem to operate as relevant environmental cues in order to regulate handsprings on vault (Heinen et al., 2011, 2013). This however may be obvious particularly in handspring vaults because gymnasts' line of sight could in general be directed towards the vaulting apparatus during the entire run-up. Yet, the question arises to which degree the position of the springboard operates as an environmental cue to regulate Yurchenko-type vaults, where the gymnast performs a round-off before contacting the springboard (Bradshaw, 2004; Koh, Jennings, Elliott, & Lloyd, 2003). In addition, in Yurchenko-type vaults a round-off mat is placed in front of the springboard, and gymnasts place their hands on the mat during the round-off. Therefore, it could be questioned whether the position of the round-off mat additionally operates as a relevant informational cue in the regulation of Yurchenko-type vaults because the mat belongs to the structure of vaulting apparatus.

Given that both, the position of the round-off mat, and the position of the springboard could operate as relevant informational cues in the regulation of Yurchenko-type vaults, it was hypothesized that gymnasts place their hands on the same spot on the round-off mat, regardless of whether the round-off mat position was manipulated. It was furthermore hypothesized that gymnasts place their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated (Heinen et al., 2011). There was no specific hypothesis on the effects of manipulating the position of the round-off

mat and/or the springboard on positions of the hands during support on the vaulting block and we sought to explore this effect. Finally, distances of flight phases should vary as a result of changes in hand and/or feet placement and we also sought to explore this effect.

METHODS

Eight female gymnasts participated in this study (*age* = 13.9 ± 2.6 years; [mean ± standard deviation]). The gymnasts in this study could be characterized as experts because they reported to take part in National Championships with an average weekly training extent of 20.8 ± 3.3 hours and an average training experience in artistic gymnastics of 9.1 ± 2.5 years (Chi, 2006). The gymnasts were able to perform the experimental task of this study (Yurchenko timer; see Motor task paragraph) under changing environmental conditions (Davids et al., 2008).

Motor task. The motor task was a so-called Yurchenko timer (Arkaev & Suchilin, 2004; George, 2010; see Figure 1 for an illustration). Timers (as drills) are usually used in gymnastics training in order to develop the 'feel' of a complex skill without the need to complete the skill (Elliott & Mitchell, 1991; Turoff, 1991). The Yurchenko timer was used as experimental task in order to ensure gymnasts' safety, especially in experimental conditions where the positions of the round-off mat and the springboard were manipulated.

After a short run-up, the gymnast performs a hurdle jump followed by a round-off. In the round-off, the hands are placed on a round-off mat. The gymnast pushes herself off the round-off mat and places her feet on the springboard. The gymnast reactively leaps off the springboard with a backward rotation about her somersault axis performing a half back somersault. She engages a support position by placing her hands on a vault block. From this support position, she pushes off the vault block and rotates to landing on her back on a soft mat. A certified springboard (1.20 meters long, 0.60 meters wide) with a safety mat and a certified round-off mat were used (1.25 meters long, 1.00 meters wide). The height of the vault block was 0.80 meters with a width of 2.00 meters and a length of 1.00 meters. It was decided to use a vault block with a standard height of 0.80 meters, because it is typically used in methodical progressions in gymnastics, and therefore additionally supports gymnasts' safety when performing the Yurchenko timers in the experimental conditions.

Movement Analysis System. The kinematic parameters of the Yurchenko timers were analyzed by means of an optical movement analysis system. All performances were videotaped by using two full-HD video cameras with a spatial resolution of 1920 x 1280 pixels, and a temporal resolution of 50 Hz. The temporal measurement error was ± 0.02 seconds, and the spatial measurement error was ± 0.004 meters. The video cameras were placed orthogonal to the movement plane of the gymnasts. The first camera videotaped the run-up phase, and the second camera videotaped the hurdle movement and the Yurchenko timer. The field of view of both cameras overlapped by approximately two meters. Both cameras were placed 20 meters away from the movement plane of the gymnasts. The position of the toes at the beginning of the run-up, during each step of the run-up, and during the hurdle, as well as the position of the hands on the round-off mat, the position of the feet on the springboard during the reactive leap, and the position of the hands during support on the vault block were recorded using the software utilius® easyinspect (CCC-Software, 2008).

Measures. In order to assess movement regulation during the run-up, the hurdle, and the Yurchenko timer, the following six variables were calculated (see also Figure 1): (1) standard deviation in footfall position during each step of the

run-up, and during the hurdle (Bradshaw, 2004; Lee, Lishman, & Thomson, 1982), (2) averaged distance of both hands to the leading edge of the round-off mat during the support phase of the round-off (average of s_{1st} and s_{2nd}), (3) distance of the toes to the leading edge of the springboard during take-off from the springboard in the Yurchenko timer (s_{feet}), and (4) distance of the hands to the leading edge of the vault block during the support phase of the Yurchenko timer (s_{hands}), (5) distance of the flight phase of the round-off ($s_{flight.1}$), and (6) distance of flight phase to support on vault block ($s_{flight.2}$). Kinematic parameters were averaged over all six trials for each gymnast in each study condition.

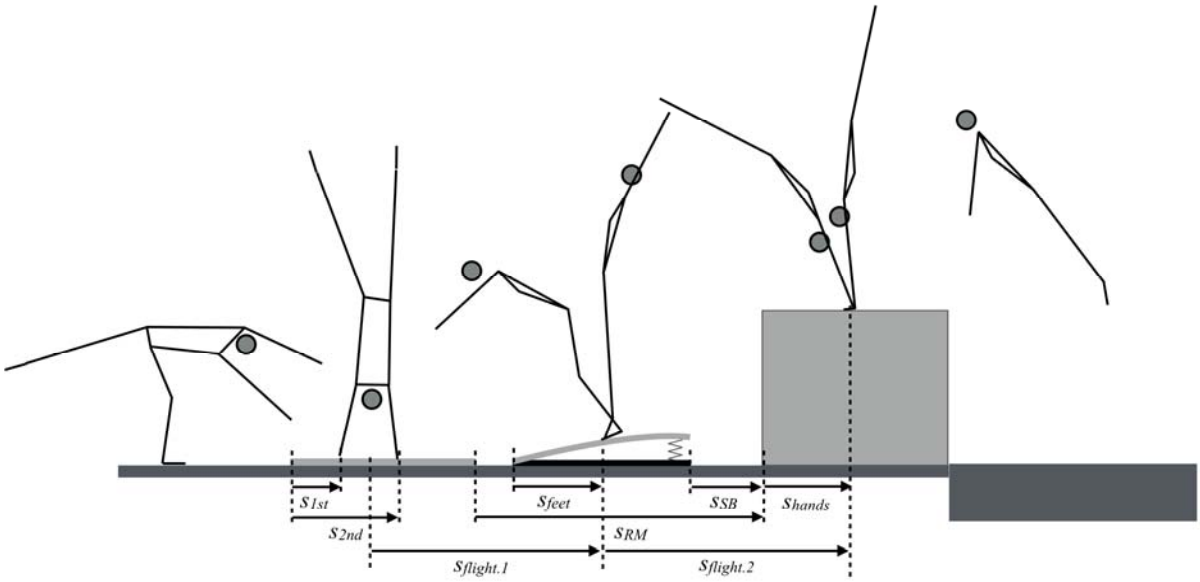

Figure 1. Stick-figure sequence of the experimental task (Yurchenko timer).

Note: s_{1st} and s_{2nd} denote distance of first and second hand to leading edge of round-off mat. s_{feet} is the distance of the toes to the leading edge of the springboard. s_{hands} indicates the distance of the hands to the leading edge of the vault block. s_{RM} and s_{SB} are the distance of the round-off mat and the distance of the springboard towards the leading edge of the vault block. $s_{flight.1}$ and $s_{flight.2}$ are the distances of the two flight phases.

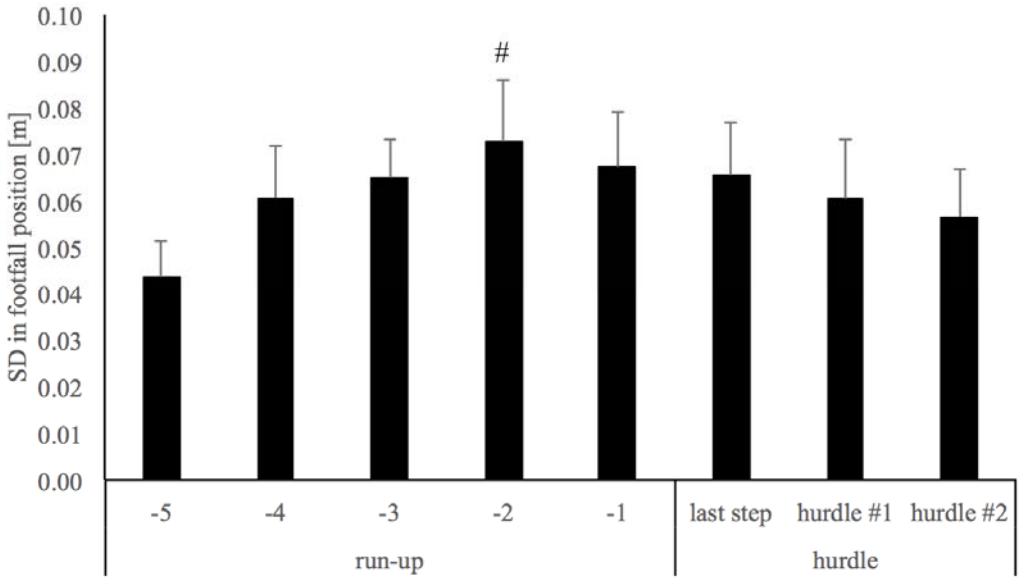

Figure 2. Standard deviations (SD) in footfall positions during the steps of the run-up, and during the hurdle movement (means ± standard deviations).

Note: The bars show aggregated values for all study conditions. The peak in standard deviation (#) occurred during the second last step prior to the hurdle movement, indicating the onset of visual regulation (Bradshaw, 2004).

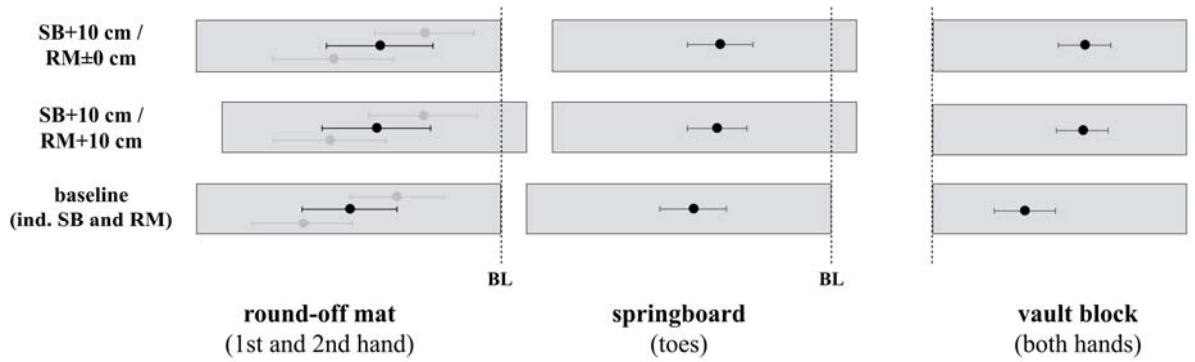

Figure 3. Illustration of the study conditions along with the means and standard deviations of (1) the averaged distance of both hands to leading edge of round-off mat during the support phase of the round-off, (2) the distance of the feet to the leading edge of springboard during the take-off phase of the Yurchenko timer, and (3) the distance of the hands to the leading edge of the vault block during the support phase of the Yurchenko timer.

Note: The baseline condition comprised gymnasts' individual distances of round-off mat and springboard to the vault block (BL = baseline, RM = round-off mat, SB = springboard).

The study was conducted in three phases. In the first phase the gymnast arrived at the gymnasium, and she was informed about the general procedure of the study. In particular, the gymnast was told that she takes part in a study on the kinematics of Yurchenko timers on vault. Contrary to the experimental approach in other studies (i.e., Heinen et al., 2011), the gymnasts were informed about the manipulation of both, the position of the springboard, and the position of the round-off mat. This was done to ensure gymnasts safety, because after placing the hands on the round-off mat, the gymnast moves and rotates backward with restricted vision to the springboard. Nevertheless, given that the gymnasts in this study could be characterized as experts, it was argued that regulation processes due to a manipulation of the round-off mat position, and the springboard position should operate, whether or not a gymnast is consciously aware of such a manipulation (Meeuwsen & Magill, 1987). The study was conducted in compliance with the Helsinki Declaration and the International Principles governing research on humans, as well as in line with the ethical guidelines of the local ethics committee.

The gymnast gave her written informed consent, and she was given a 20-minute warm-up period. After warm-up, the gymnast was allowed three familiarization trials. In the familiarization trials, the round-off mat and the springboard were placed at gymnasts' individual distances thereby reflecting the baseline condition. In the second phase, the gymnast performed 18 Yurchenko timers, six in each experimental condition, and six in the baseline condition. The gymnasts began with the baseline trials. The remaining 12 trials of the two experimental conditions were presented in a randomized order. An instructed experimenter placed the springboard and/or the round-off mat according to the individual experimental protocol for each gymnast. Prior to each trial, the gymnast was informed about the experimental manipulation. Each gymnast was allowed to take breaks as requested and there was no time pressure. In the third phase, and after completing the 18 Yurchenko timers, the gymnast was given an individual cool-down period, she was debriefed, and received a gift as reward for participation in this study.

As significance criterion $\alpha = 5\%$ was defined a-priori. Gymnasts exhibited in average five run-up steps in each of the experimental conditions, and in the baseline condition. The standard deviation method was applied in order to evaluate standard deviations in footfall position during each step of the run-up and during the hurdle (Bradshaw, 2004; Lee et al., 1982). In order to assess the influence of a manipulation of both, the positions of the round-off mat and the springboard on the dependent variables, separate Wilcoxon matched pairs tests were calculated between the baseline condition and each experimental condition.

RESULTS

Onset of visual control was expected to take place two steps prior to the hurdle, independent of the experimental condition (Bradshaw, 2004). It was hypothesized that gymnasts place their hands on the same spot on the round-off mat, regardless of whether the round-off mat position was manipulated. It was furthermore hypothesized that gymnasts place their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. There was no specific hypothesis on the effects of manipulating the position of the round-off mat and/or the springboard on positions of the hands during support on the vaulting block and we sought to explore this effect. Finally, distances of flight phases should vary as a result of changes in hand and/or feet placement and we also sought to explore this effect.

Peak in standard deviation in footfall position during run-up could be identified

in the second last step prior to the hurdle in the baseline condition as well as in the experimental conditions. Comparing the baseline condition with experimental conditions, revealed neither statistically significant differences in standard deviations in footfall positions in the run-up, nor in the hurdle (all $p > .05$). Figure 2 thus illustrates the aggregated values for the experimental conditions and for the baseline condition.

In the baseline condition, gymnasts placed their hands 0.60 ± 0.19 metres from the leading edge of the round-off mat during the support phase of the round-off. The toes were placed 0.65 ± 0.13 metres from the leading edge of the springboard during the reactive leap, and the hands were placed 0.36 ± 0.12 metres from the leading edge of the vault block during support on the vault block. The distance of the round-off flight phase was 1.35 ± 0.09 metres, and the distance of the flight phase from reactive leap to support on the vault block was 1.31 ± 0.11 metres (see Table 1 for details).

When both, the springboard and the round-off mat were placed 10 centimetres closer to the vault block (SB+10 cm / RM+10 cm condition), the following pattern of results emerged: Gymnasts placed their hands in average on the same spot on the round-off mat ($Z = 0.56$, $p = .57$). They also placed their feet on average on the same spot on the springboard ($Z = 0.14$, $p = .89$). However, distance of the hands during support on the vault block was in average 0.23 metres longer compared to the baseline condition ($Z = 2.52$, $p = .01$). The distance of the round-off flight phase was not significantly different from the baseline condition ($Z = .28$, $p = .78$), whereas the distance of the flight phase to support on the vault block was 0.13 metres longer compared to the baseline condition ($Z = 2.52$, $p = .01$, see Figure 3 for an illustration).

When the springboard was placed ten centimetres closer to the vault block, and the round-off mat was placed at baseline position (SB+10 cm / RM±0 cm condition), the following pattern of results emerged: Gymnasts placed their hands 12 centimetres closer to the back edge of the round-off mat ($Z = 2.52$, $p = .01$). They placed their feet on average on the same spot on the springboard ($Z = 0.14$, $p = .89$). However, distance of the hands during support on the vault block was in average 0.24 metres longer compared to the baseline condition ($Z = 2.52$, $p = .01$). Distance of round-off flight phase was the same as in the baseline condition ($Z = 1.40$, $p = .16$), and distance of flight phase to support on the vault block was 0.14 metres longer compared to the baseline condition ($Z = 2.24$, $p = .03$).

DISCUSSION

Results revealed that when performing Yurchenko timers, the onset of visual control occurred in the run-up, two steps prior to the hurdle. Hand positioning on the round-off mat preceded a rather constant round-off flight phase. Gymnasts placed their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. Hand positioning on the vault block mainly varied as a function of the springboard position and the distance of the flight phase to support. If we summarize the results of the study, it becomes apparent that female expert gymnasts predominantly use the springboard as informational source to regulate Yurchenko timers on vault. Onset of visual control inferred from standard deviation in footfall position occurred in average two steps prior to the hurdle in all study conditions, thus indicating that the perception of environmental cues is likely to take place in the last part of the run-up, prior to the hurdle. This result supports the notion of an anticipatory control strategy to time and regulate current action (i.e., run-up) to future events and event-related effects (i.e., placement of feet on springboard; Bardy & Laurent, 1998; Hoffmann et al., 2004;

Turvey, 1992). Gymnasts seem to anticipate the reactive leap from the springboard already prior to the round-off, and they regulate the run-up accordingly. This result is in line with findings of Bradshaw (2004) and Meeuwsen and Magill (1987). However, comparing the results of the current study with the results of other studies (e.g., Heinen, Artmann, Brinker, & Nicolaus, 2015), one could argue that onset of visual regulation might be (to some degree) task-dependent (see also Bradshaw, 2004). Theories of visual and attentional expertise suggest that it is not only important *which* informational cues are used in movement regulation but also *when* these cues are used (Gegenfurtner et al., 2011; Land, 2006). It seems that skilled gymnasts possess specific memory representations so that they know at which distance they need to pick up which information in order to regulate the run-up with the aim of a precise interaction with the vaulting apparatus during complex skills, such as a Yurchenko timer.

The round-off mat does not seem to be a strong cue on movement regulation in the performance of the Yurchenko timers. For instance, gymnasts have to place their feet on a particular area on the springboard in order to achieve optimum recoil during take-off, given the elastic properties of the springboard (Čuk & Karacsony, 2004). The elasticity of the round-off mat, however, is rather equally distributed, and there is in general no necessity to place the hands on a particular spot on the round-off mat (as long as there is enough space left; George, 2010). This argumentation receives support from a comparison of gymnasts' motor behaviour in the experimental conditions, and in the baseline condition. One may speculate that performing a rather constant round-off flight phase could be one important strategy in the performance of Yurchenko timers, as long as there is enough space left on the round-off mat to place one's hands during the round-off.

Table 1
Gymnasts' kinematic parameters (means ± standard deviations) of the Yurchenko timers on vault in the two experimental conditions, and in the baseline condition.

		Conditions	
Variables	Baseline (ind. SB and RM)	SB+10 cm / RM+10 cm	SB+10 cm / RM±0 cm
s1st2nd [m]	0.60 ± 0.19	0.61 ± 0.21	0.72 ± 0.21*
sfeet [m]	0.65 ± 0.13	0.65 ± 0.12	0.65 ± 0.14
shands [m]	0.36 ± 0.12	0.59 ± 0.10*	0.60 ± 0.10*
sflight.1 [m]	1.35 ± 0.09	1.34 ± 0.12	1.33 ± 0.09
sflight.2 [m]	1.31 ± 0.11	1.44 ± 0.11*	1.45 ± 0.12*

Note: * denotes statistical significant difference ($p < .05$) between the particular experimental condition, and the baseline condition (RM = round-off mat, SB = springboard).

Onset of visual control inferred from standard deviation in footfall position occurred in average two steps prior to the hurdle in all study conditions, thus indicating that the perception of environmental cues is likely to take place in the last part of the run-up, prior to the hurdle. This result supports the notion of an anticipatory control strategy to time and regulate current action (i.e., run-up) to future events and event-related effects (i.e., placement of feet on springboard; Bardy & Laurent, 1998; Hoffmann et al., 2004; Turvey, 1992). Gymnasts seem to anticipate the reactive leap from the springboard already prior to the round-off,

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At the same time, however, the springboard seems to be a more important cue when performing Yurchenko timers compared to the round-off mat. Gymnasts placed their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. This result is consistent with findings of Heinen et al. (2011, 2013), thereby supporting the notion that the position of the springboard operates as informational source to regulate Yurchenko timers on vault. Even if gymnasts are unable to "see" the springboard position during the second part of the round-off (when their back is facing the springboard, and thus their line of sight is directed away from the springboard) it seems plausible that they perceive the position of the springboard during the (last part of the) run-up, thereby again supporting the idea of an anticipatory control, thus enabling the gymnasts to precisely hit the springboard at the end of the round-off. One could argue that gymnasts compare the position of the springboard with their long-term memory representation of the movement, and the appropriate places of the springboard. In addition, in both of the experimental conditions the springboard was placed closer to the vault block, thus affording a slightly longer run-up, which may have resulted in a slightly more dynamic round-off, which in turn resulted in a longer flight phase to support on the vault block.

There are several limitations of the study which should be highlighted. First, the position of the springboard and the round-off mat were manipulated in steps of ten centimetres. One could argue that a stronger manipulation could lead to different effects on movement regulation of the Yurchenko timer. It could for instance be of interest to assess the relationship between the strength of manipulating positional environmental cues and gymnasts' regulation capacity when dealing with these manipulations.

Second, gymnasts were informed about the manipulation of both, the position of the springboard, and the position of the round-off mat mainly for

safety reasons. However, one cannot be sure whether this information influenced the results of this study. Prior knowledge about the experimental manipulation could lead to a different anticipation process and therefore to a different motor behaviour. Nevertheless, it is suggested to investigate the influence of prior information on gymnastics tasks incorporating restricted vision with less environmental constraints, such as round-off, back handspring and back somersault on floor, where the primary aim is not to precisely hit a springboard, but rather to land inside the limited area of the floor apparatus.

Third, expert gymnasts are thought to be already attuned to task-relevant informational sources (Raab et al., 2009). The question, however, could be how the role of informational cues change over the process of motor skill acquisition. While it may be helpful for a novice gymnast to use the round-off mat as a relevant cue when performing the round-off (in order to acquire an adequate round-off technique with a constant flight phase and thus to prevent 'flying over' the springboard), the round-off mat may not be a relevant cue any more for an expert gymnast because he/she already acquired an adequate round-off technique. A subsequent study should thus assess the role of the round-off mat as an informational cue for novices' motor behaviour in Yurchenko timers.

There are, however, some practical consequences and implications that can be concluded from the current study. Gymnastics involves numerous skills with unique technical requirements (Sands, Caine, & Borms, 2003). Therefore, for gymnasts an adaption to varying conditions is essential, not only regarding different task requirements but also regarding physical and psychological changes between training and competition. It could therefore be fruitful for the learner to practice Yurchenko-type vaults under varying conditions, and with varying movement patterns in order to develop a broad range of regulation strategies. This could easily be achieved by practicing Yurchenko-type vaults with different run-up lengths, as well as with different positions and distances between the round-off mat, the springboard, and the vaulting table. A particular emphasis should be placed on the acquisition of adequate movement technique of the round-off (i.e., optimum flight phase; see also Bradshaw, 2004, for further ideas). Applying a *differential learning approach* (Schöllhorn, Hegen, & Davids, 2012) might support the development of functional movement strategies together with its corresponding long-term memory representations especially in complex tasks, such as a Yurchenko on vault. It is thus important for the gymnast to engage in a functional between-trial processing because this may support long-term memory formation and retention (Schack & Ritter, 2009; Schöllhorn et al., 2012). This might also help to overcome potential problems related to practice specificity and context dependence (Keetch, Lee, & Schmidt, 2008; Schmidt, Young, Swinnen, & Shapiro, 1989).

This study provides evidence that the position of the springboard regulates Yurchenko-type vaults in female expert gymnasts. Knowledge about relationships between informational sources in the environment and the resulting motor behaviour in gymnasts may help coaches to develop training programs aiming to enhance gymnasts' ability to use visual information during the approach run and to regulate their movements under changing environmental conditions in training and competition.

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POTENTIAL BENEFITS OF CONSUMING OMEGA-3 FATTY ACIDS FOR ARTISTIC GYMNASTS

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Review article

Abstract

For an efficient daily training of gymnasts and, at the end, for an efficient performance, it is important to have an energy- and nutrient-sufficient diet, which enables a proper balance between maintaining appropriate body composition, excellent physical preparation, and general health. The combination of an intake of negative-calorie food and an increased amount of training, which enables the control of body weight, can have negative consequences when it comes to nutritional inadequacy, which can lead not only to a weakened immune system but also to an insufficient recovery after daily trainings. Today, athletes as well as gymnasts consume various dietary supplements to improve physical and cognitive abilities, for a more efficient recovery, a stronger immune system, and an easier control of appropriate body weight. A sufficient intake of omega-3 fatty acids – as is also true of vitamin B_{12} and D – is usually a part of a special assessment of dietary habits and needs of gymnasts, which they can fulfil with ordinary diet or dietary supplements. The purpose of this article is to relatively clearly evaluate the scientific evidence about the potential benefits of consuming omega-3 fatty acids (ALA, EPA, and DHA) for a variety of objectives for gymnasts and, at the end, to critically sum them up in a sensible recommendation, while being aware of limitations of the evidence. Furthermore, this article is intended to encourage researchers to study the direct influence of nutrition and potentially beneficial and permitted dietary supplements for a variety of objectives for gymnasts.

Keywords: *body weight, physical ability, cognitive abilities.*

INTRODUCTION

Omega-3 fatty acids are an essential nutrient that is vital for the functioning of the immune system, brain development, and cognitive functioning, while at the same time having an anti-inflammatory effect. Humans ordinarily consume omega-3 fatty acids, which are synthesized only by plants, through the consumption of sea fish or dietary supplements. If they do not consume any of these two, they are at risk due to a possible deficiency, such as increased vulnerability to impaired cognitive functions and brain structure, increased emotional behavior and decreased visual capacity, mood disorders and decreased immune function (Simopoulos, 2013). Despite the existing recommendations of the World Health Organization (WHO) and the European Food Safety Authority (EFSA) about the recommended intake of essential omega-3 fatty acids (ALA – alpha-linolenic acid)

and "half essential" derivatives of omega-3 fatty acids (EPA, i.e. eicosapentaenoic acid and DHA, i.e. docosahexaenoic acid*) (EPA and DHA are not technically "essential" because they can be produced endogenously, but the process is slow and inefficient and is affected by genetics, sex, age, and dietary composition (Saunder, Davis & Garg, 2013)),* there exists a concern from the side of the gymnasts about the potential inadequacy of the intake of omega-3 fatty acids due to different qualities of nutrition, which controls the energy intake. There is also the need to evaluate the studies that have proven the potential benefits of consuming omega-3 fatty acids in the form of dietary supplements on the improvement of body composition, physical and cognitive abilities, and recovery. Gymnasts also wish to know whether the fish that contain also non-essential fatty acids (e.g. saturated fat) *(Fats are usually divided into two categories (Haver, 2016): essential (EFAs) and non-essential fatty acids (non-EFAs). EFAs belong to the group of polyunsaturated fats – PUFA (i.e. α-linolenic acid or ALA, omega-3 fatty acid and linoleic acid or LA, omega-6 fatty acid) and since the body cannot synthesize them, it must obtain them from food. Plants are generally the original source of both types of PUFA in the food chain (found in seeds and their respective oils, soybean, microalgae, fish, and marine oils). Non-EFAs, which the body does not need to get from food, belong to the group of monounsaturated fats – MUFA (found in olives, avocados, certain nuts and seeds and their respective oils; considered neutral or potentially beneficial) and saturated fats – SFA (found in animal products, vegetable oils, and tropical fats such as palm and coconut; can promote CVD). Trans fatty acids – TFA are also non-EFAs but are laboratory-made via hydrogenation and are found in processed, fried, and fast food and are not considered safe)* are even a healthy and a representative food for the intake of essential omega-3 fatty acids, given the fact that it does not synthesize the omega-3 fatty acids by itself, especially in addition to the total food intake that already contains a lot of saturated fat and the fact that a fish may be potentially quite contaminated with industrial chemicals. They also wonder if we really need EPA and DHA in addition to ALA, which are known as essential fats, and what the risks are of regular consumption of fish or EPA and DHA dietary supplements, extracted from fish oil or seaweed. Contradictory evidence, which is usually the result of different study designs, erroneous interpretations, conflicts of interest of researchers, and consequently contradictory information, which appears in various sports media, does not always offer credible information to the gymnasts and, consequently, affects making the right decisions.

Characteristics of competitive artistic gymnastics

A successful performance on the floor, the pommel horse, the rings, the vault, the parallel bars, and the horizontal bar requires a number of motor skills, such as speed, strength, endurance, agility, flexibility, and balance, while the level of gymnast's skills is tightly connected with the absence of injury (Sleeper, Kenyon, Elliot & Cheng, 2012). Appropriate body weight, excellently developed motor skills, and a high level of various perceptual abilities enable the gymnasts to control their posture while executing demanding elements, despite the fact that they cannot completely rely on their eyesight. Because competitive gymnastics (Marina & Rodríguez, 2014) demands a combination of explosive and submaximal muscle contractions when executing numerous demanding elements, there is also a relatively high heart rate (from 170–190 beats/min with women and from 150–180 beats/min with men). Due to repetitive gymnastics elements with short breaks (lasting up to 90 seconds), competitive

gymnastics primarily includes anaerobic metabolism (average assessment is 80% of energy requirements) and blood lactate concentration between 8 and 11 mmol/L. The performance on the floor can be an exception in certain cases, because there remains a possibility that the gymnast will reach up to 85% of maximal oxygen consumption (Marina & Rodríguez, 2014). So we can see that appropriate eating habits are very important for an efficient execution at trainings and at competitions. Due to the repetitive trainings, gymnasts usually train in a constant state of fatigue, while pushing their physical and cognitive abilities to the maximum limit. Muscular and nervous fatigue can weaken the immune system and general health, decrease efficient recovery and, consequently, the quality of trainings and performances, and can increase the possibility of injuries, especially due to calorie restriction, inappropriate diet, and potential nutrient deficiency of certain nutrients (among others also omega-3 fatty acids). At some point, the ability to efficiently control body weight while simultaneously maintain a high level of motor skills is made more difficult, which also includes special physical preparation. According to our knowledge, the published studies about gymnasts that are available at the moment did not measure the levels of omega-3 fatty acids in the blood, nor the direct influence of the intervention of omega-3 fatty acids (ALA, EPA, and DHA) or the potential benefits and risks of long-term deficiency of its intake on general health, the improvement of physical and cognitive abilities, and a successful control of appropriate body weight. Based on everything stated above, the authors will present this problem in this article from different viewpoints, because there is a lack of complete information about the effects and benefits of consuming omega-3 fatty acids for the needs of artistic gymnasts.

The history of popularization of omega-3 fatty acids

Essential omega-3 fatty acids have been a very well researched nutrient in the last decades and among all the alleged benefits its most positive proven effect is on cardiovascular health. It all started with anecdotes about the Eskimo who lived in extreme circumstances and consumed a lot of fish and various sea animals, rich in omega-3 fatty acids or, in other words, high-fat food with a lot of dietary cholesterol and practically without any fiber, while showing a very low incidence of cardiovascular diseases, cancer, or chronic diseases in general. In literature, the Eskimo paradox first appeared in the middle of the 1970s, when Bang and Dyerberg carried out a research which did not study the incidence of cardiovascular disease and attributed a protective role against chronic diseases to omega-3 fatty acids (Fodor, Helis, Yazdekhasti & Vohnout, 2014). Already in the 1930s, scientists refuted the supposition about the absence of atherosclerosis among the Eskimo (Rabinowitch, 1936). Furthermore, scientists retrieved the remains of the Eskimo that have been frozen for thousands of years and they saw the presence of atherosclerosis (Zimmerman, 1993). An examination of mummified remains of the Eskimo with the help of a *computed tomography (*CT) scanner clearly indicated atherosclerosis of the blood vessels of the heart, brain, and legs, which contradicts general belief that atherosclerosis is more a disease of the modern age (Thompson et al., 2013). Fodor et al. (2014) conclude that a comprehensive overview of scientific evidence proves that the Eskimo have a similar incidence of atherosclerosis as the rest of the world, a higher mortality rate due to heart attack, twice as high general mortality rate, and a lifespan that is ten years shorter than e.g. the lifespan of the Danish. The authors rhetorically asked themselves why numerous researchers uncritically cite the research by Bang and

Dyerberg as proof that the Eskimo have a lower incidence of cardiovascular disease when this is scientifically not entirely correct. Therefore, those types of claims are either a result of misinterpretation or a case of study's bias. Despite the fact that there is a need for more well-designed studies that would strengthen the position of omega-3 fatty acids in the science of nutrition and nutrients, there is quite a high amount of scientific evidence connected with the potential benefits and protective effects of omega-3 fatty acids.

Sources of omega-3 fatty acids

Omega-3 fatty acids consist of short chains (ALA) and long chains (EPA and DHA) of omega-3 fatty acids. ALA can be found in flaxseeds, hemp seeds, and chia seeds, in walnuts, soya, and, in smaller amounts, also in dark green vegetables, e.g. Brussels sprouts, spinach, and sea vegetables, while EPA and DHA are present in marine microalgae and plankton and also in fish that feed on marine microalgae *(the fish get EPA and DHA from a primary source, i.e. by consuming seaweed. The amount of EPA and DHA fatty acids in certain types of fish depends on their environment and the type of the consumed seaweed)* e.g. salmon, sardines, tuna, mackerel, and others. The World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), and the European Food Safety Authority (EFSA) specify the recommended daily intake for adults (RDI), which is 0.5% (up to 2 grams) of ALA calories (FAO, 2010). According to the Academy of Nutrition and Dietetics (AND), a person may already consume the RDI of ALA with one spoon of flaxseeds and chia seeds, and partly by eating dark green vegetables and various berries (Vannice & Rasmussen, 2014). Even though our body can synthesize EPA and DHA from ALA, clinical studies have shown a potential inadequate or inefficient conversion, which results in the current consensus of WHO and EFSA that it is recommended to consume – especially for the health of a pregnant woman, a nursing mother, and the proper development of the fetus – at least 250 mg of EPA and DHA from the source of sea fish or marine microalgae (Flock, Harris & Kris-Etherton, 2013). Meanwhile, Simopoulos (2007) states, based on the available scientific evidence, that it is recommended for most athletes to consume omega-3 fatty acids in quantities of 1–2 g of EPA and DHA daily in the ratio 2:1. If we think about the benefits and potential risks, we can see that fish is not the most appropriate source of EPA and DHA, because it is contaminated with polychlorinated biphenyl (PCB), dioxin, mercury, and other heavy metals (Jacobs, Ruzzin & Lee, 2014). The Slovenian Jožef Stefan Institute measured the content of mercury in 52 fresh fish and 56 canned fish on the Slovenian market and discovered that with a typical portion (100 g) of fresh fish we consume from 58% to 1940% of mercury, while with a typical portion of canned fish we consume from 3% to 1556% of the permitted daily intake of mercury (Zajc, 2006). A recent study, conducted in five EU countries (Belgium, Ireland, Italy, Portugal, and Spain), which assessed the risks of the contamination of fish with different chemicals from the environment, showed a typical contamination with mercury in tuna, hake, cod, bream, sea bass, and octopus. The authors state that these results and the examination of the results from other authors indicate a justified need to inform people about the benefits of consuming certain fish as well as the potential health risks (Jacobs et al., 2016). Most of the fish is not only contaminated with mercury (Nielsen, Kit, Aoki & Ogden, 2014) and PCBs, but also party contaminated with dioxin and chlorinated pesticides, which have harmful effects on the nervous, immune, and cardiovascular system (Bushkin-Bedient & Carpenter, 2010). On the other hand, the most widely used dietary supplements with omega-3 fatty acids on the market are produced

exactly from fish oil. Numerous companies usually clean the various industrial chemicals found in fish oil, but these processes of removal are not always effective with fat-soluble toxins, such as dioxin and PCB (Fernandes, Rose, White, Mortimer & Gem, 2006). In addition, in many cases there exists a well-founded concern about the potential oxidation of fish oils due to the potential presence of heavy metals, inappropriate composition of fatty acids, exposure to oxygen, light, and temperature, the content of antioxidants, and the presence of water (Cameron-Smith, Albert & Cutfield, 2015). We should devote special attention to fish when an individual is allergic or sensitive to it or to fish oils or when an individual is taking certain pills (e.g. for thinning the blood or lowering blood sugar). However, fish oils are in general considered as a dietary nutrient without negative side effects (NIH, 2015), given that we control the factors that may influence their adulteration. In addition to the already mentioned potential problems, there remains the concern of increased environmental pressure (the increasing number of population, global warming) on the fish population, which poses a legitimate question about the adequacy of consuming fish or fish oils (Kang, 2011). On the other hand, the market offers more and more EPA and DHA dietary supplements that are produced from laboratory cultured seaweed and are, from the standpoint of clinical efficiency, comparable with fish oil, without any traces of industrial chemicals (Doughman, Krupanidhi & Sanjeevi, 2007). There are also no signs of digestive problems (diarrhea) or any consequences of the taste of fish after consumption (burping) or belching (Neff et al., 2011).

Potential inadequacy of EPA and DHA omega-3 fatty acids

Numerous professionals for maintaining optimal health advocate the consumption of either fish or omega-3 fatty acids (EPA and DHA) in the form of dietary supplements. Their arguments are, firstly, that the body cannot efficiently convert the essential omega-3 fatty acids (ALA) into EPA and DHA and, secondly, that certain individuals do not consume (enough) fish, which are a rich source of EPA and DHA. Under the term "omega-3 fatty acids" we usually think of the essentially short chain of omega-3 fatty acids (ALA), which the body converts into SDA (i.e. *stearidonic acid), EPA, and DHA* omega-3 fatty acids. SDA can be directly consumed with blackcurrant, hemp seeds, or fish, and EPA and DHA with fish or eggs, sea vegetables (EPA), and marine microalgae (EPA and DHA). The conversion from ALA into EPA and DHA is slow and inefficient and generally depends on heredity, gender, age, and dietary patterns *(under the dietary factors we consider a large enough intake of ALA, consuming food that helps with the conversion of ALA into EPA and DHA (e.g. fruit and vegetables), an inadequate intake of protein and fasting, consuming food that inhibits the process (e.g. saturated and trans fats, too much omega-6 fatty acids, dietary cholesterol, alcohol), direct intake of DHA from the source of sea fish or marine microalgae, while under the non-dietary factors we count age (when we get older the conversion decreases), gender (women have better synthesis), chronic diseases (diabetes, high blood pressure, high cholesterol), smoking, and hereditary differences Saunder, Davis & Garg, 2013).* Scientists assess that the body can convert approximately 0.3 to 21% of ALA into EPA and 0–9% into DHA, while women, compared to men, have a significantly higher percentage of converting ALA into EPA (Burdge, Jones & Wootton, 2002; Burdge & Wootton, 2002), but not ALA into DHA (Childs et al., 2014). If the intake of omega-6 fatty acids (e.g. consuming various types of vegetables oils) is too high, it may slow down the process of conversion for up to 40–54% (Emken, Adolf & Gulley, 1994;

Gerster, 1998), while a low-fat diet and calorie restriction improve the level of conversion of ALA into EPA and DHA (Das, 2006). A randomized controlled cross-over study measured the effect of a low-fat (20% of fat) and high-fat diet (45% of fat) lasting for 12 weeks, where the two diets had the same amount of calories and a similar ratio between omega-6 and omega-3 fatty acids. The researchers discovered that the low-fat diet enabled a higher percentage of conversion of ALA into EPA and DHA compared with the high-fat diet (Raatz, Bibus, Thomas & Kriss-Etherton, 2001). On the other hand, a direct intake of DHA, e.g. by eating fish, eggs, or dietary supplements, slows down the process of conversion of ALA into EPA and DHA from 72% to 88%, which means that we can potentially increase the percentage of conversion of ALA into DHA by not eating the direct source of DHA (e.g. fish) (Emken, Adolf, Duval & Nelson, 1999; Welch, Shakya-Shrestha, Lentjes, Wareham & Khaw, 2010). Smoking during pregnancy also results in worsening the conversion of ALA into EPA and DHA in the breast milk (Marangoni et al., 2004). Scientifically speaking, it is undisputable that humans do not need to consume fish at any stage of their life in order to achieve optimal health, but they do need ALA. Clinical interventions in people with a previous lack of consuming DHA from a direct source show that DHA is most likely a half-essential fatty acid. Health authorities for adult males and non-pregnant/non-lactating adult females recommend daily intakes of EPA and DHA ranging from 250 to 550 mg/day (FAO, 2010; Harris et al., 2009). People can consume it from more representative and less unhealthy sources than directly eating different types of fish rich in EPA and DHA, which can also be applied to gymnasts.

Omega-3 fatty acids and diets without fish or vegan diets

Our body is able, with the right amount and ratio between omega-6 (LA) and omega-3 fatty acids (ALA), to synthesize DHA and EPA from the essential ALA, but it often raises the question of sufficiency, which is why today there is a scientific consensus that DHA are most likely essential fats. Rosell et al. (2005) discovered that the concentration of ALA in the blood plasma is similar with vegetarians and non-vegetarians, while the concentration of EPA and DHA is lower with vegetarians (28% and 31%) and even lower with vegans (53% and 59%), but that it is stable. *(Welch et al. (2010) discovered that people who do not eat fish (vegans, vegetarians who do not eat fish, "carnivores" who do not eat fish) consume from 57% to 80% less omega-3 fatty acids in comparison with people who eat fish, although the differences in the index of omega-3 fatty acids in the blood plasma are then smaller, most likely due to the already discovered better conversion of ALA into EPA and DHA with people who do not eat fish).* .In one study (Sarter, Kelsey, Schwartz & Harris, 2015) the researchers wanted to define the index of omega-3 fatty acids in 165 long-term vegans and the differences between different age groups and gender and compare this measured index with people who have an omnivorous diet. The researchers also wanted to determine the extent to which this index of omega-3 fatty acids *(a biomarker that is expressed as the percentage (%) of EPA and DHA content in red blood cells based on the entire amount of fat in red blood cells)* can improve by prescribing 46 participants with the initial index lower than 4% (authors assume that anything lower than 4% is undesirable) a daily dietary supplement of 254 mg of EPA and DHA from seaweed for four months. They discovered that two thirds of the assessed vegans have an index of omega-3 fatty acids that is lower than 4% (even though

they consume enough ALA), but this is in general similar to people who have omnivorous diet (the control group) and who also do not consume fish on a regular basis (3.5%). Even though it is not exactly clear whether a lower index of omega-3 fatty acids has negative consequences on health, the authors conclude that vegans from this study improved their index above 4% after the four-month supplementation. To conclude, the results of epidemiological research consistently suggest that a long-term deficiency of DHA in vegans presents a potential risk for impaired cognitive functioning in a later period of life. But, on the other hand, there is no direct evidence that the rise in the index of omega-3 fatty acids has an additional positive effect on their health, which is already protected by a vegan diet.

Consuming fish or omega-3 dietary supplements and health throughout life

Omega-3 fatty acids are polyunsaturated fatty acids, which are present in certain types of food. They are a part of the essential nutrients, which means we are supposed to consume them daily with our food. They represent vital components of various cell structures of the brain, the nervous system, the cell membranes, and chemical processes, and they are also responsible for the transfer and oxidation of cholesterol. In various studies (discussed below) EPA and DHA were connected with an improved general and cardiovascular health (the main cause of death in Western societies), improved cognitive and physical abilities, control of body weight, fetal development during pregnancy, and various diseases, which is the reason why many scientists recommend a regular consumption of fish or omega-3 dietary supplements. An overview of randomized controlled studies conducted on a number of people and of double-blind placebo-controlled studies, which examined the influence of consuming fish or fish oils (EPA and DHA) in the form of dietary supplements, showed that this type of intervention is not justifiable for the needs of primary or secondary prevention against cardiovascular diseases (Greene, Ashburn, Razzouk & Smith, 2013; Kowey, Reiffel, Ellenbogen, Kromhout, Giltay & Geleijnse, 2010; Kwak, Myung, Lee & Seo, 2012). Even a decade ago, a systematic overview of 48 randomized controlled studies and 41 cohort studies did not show any positive effect of consuming fish or fish oil on health or, in other words, a lower incidence of cardiovascular disease and cancer or a lower mortality rate (Hooper et al., 2006). Cundiff, Lanou, and Nigg (2007) emphasize that a credible research that would confirm the inverse relationship between consuming fish and omega-3 fatty acids from the source of dietary supplements and the incidence of cardiovascular disease does not exist. A lower incidence is most likely a consequence of dietary factors (in general a healthier eating pattern) and a lifestyle that is a result of people who are more aware and also eat fish. It is generally accepted that decreasing the amount of saturated fats and dietary cholesterol in food (meat and meat products, milk and dairy products, eggs, fish, oils), not smoking, and regular physical exercise reduces the risk of cardiovascular disease. Based on examining the results of 20 randomized controlled studies of adults, which measured the effect of consuming omega-3 fatty acids on the primary and secondary prevention of cardiovascular disease, Rizos, Ntzani, Bika, Kostapanos, and Elisaf (2012) discovered that the supplementation with omega-3 fatty acids is not connected with a lower risk of mortality from any reasons. In the past, some studies showed the benefits of consuming fish and fish oil in the form of dietary supplements on cardiovascular health, while recent studies do not confirm this, most likely due to a lower quality of modern nutrition, which cannot be improved by simply consuming contaminated and inadequately prepared

fish, which also contain a high level of saturated fat and dietary cholesterol, or by consuming a few pills of dietary supplements. An in-depth overview of a few studies that showed the potential benefits of consuming fish and fish oil, in comparison with those studies that did not show that, revealed that there is basically no controversy, since the main problem of intervention studies (in addition to the potentially rancid fish oil) is the surplus of the prescribed 3 g of fish oil. Studies indicate a problematic negative influence of the amount of EPA and DHA higher than 1 g or, in other words, we get a U-shaped curve of the influence of consuming omega-3 fatty acids on health, where an intake that is too small or too large presents a health risk, especially for atrial fibrillation, which is the most common disorder of heart rate in adults (Metcalf et al., 2014) that significantly increases the risk of a stroke. An appropriate, but not exceeded, intake of EPA and DHA can have a positive influence on cardiovascular health. Most likely one of the best studies in recent years assessed the benefits and risks of an adequate level of EPA and DHA in 2692 participants without any cardiovascular diseases and with an average age of 75 years. Here, the researchers relied on the measurements of blood and discovered that an intake of 250–400 mg of EPA and DHA results in a lower mortality rate due to cardiovascular diseases (Mozaffarian et al., 2013). Observational and interventional studies that examine the influence of a certain type (monounsaturated and polyunsaturated, saturated, and trans fat) or the amount of fat on the factors and the incidence of cardiovascular disease clearly state that a higher intake of trans fat and saturated fat leads to a higher incidence of cardiovascular disease, while a higher intake of omega-3 fatty acids leads to a lower incidence of cardiovascular disease. These findings do not support the interventional study in a consistent or statistically significant manner. A reductionist approach to the study, which wishes to measure the difference by increasing or decreasing one nutrient or a certain type of food, rarely brings the expected health outcomes. At the same time, this type of study bares no greater utility value, since it is a dietary pattern that makes a difference in the end.

Competitive gymnastics is, among other things, a sport discipline "for life" and gymnasts are first and foremost people and that is why it is ethical that their sports goals are not achieved at the expense of their health. Gymnastics is also a sport discipline with a majority of female population *(e.g. data for Portugal for the year 2012 shows that from the sample of 14742 gymnasts from all gymnastic disciplines 81.2% are female and only 16.7% are male (Silva & Barata, 2016). In the USA (USAGym, 2016) there are over 5 million registered gymnasts over the age of 6 and the majority of them are female (76%))* so it is probably worth stressing the importance of consuming omega-3 fatty acids as an essential nutrient that a person does not consume naturally from a representative source in the event they are not properly informed or do not have a properly planned diet. Gymnasts often end their career in the late teenage years or early 20s and many take on various roles in the world of gymnastics, so it seems reasonable that female gymnasts acquire information about the importance of omega-3 fatty acids in connection with motherhood and breastfeeding, which is what usually follows after the period of performing in competitions. There is also a justified concern that many female gymnasts, especially in the time of puberty, develop an eating disorder (energy deficiency and nutritional insufficiency), which is usually connected with dissatisfaction with appearance and the attempt to improve their performance (Nordin, Harris & Cumming, 2003). Eating disorders *(eating disorder in athletes is characterized by a wide spectrum of maladaptive eating and weight control*

behaviors and attitudes. These include concerns about body weight and shape; poor nutrition or inadequate caloric intake, or both; binge eating; use of laxatives, diuretics, and diet pills; and extreme weight control methods, such as fasting, vomiting, and excessive exercise (Bonci et al., 2008)), which are proven to be connected with hormonal imbalance (reproductive disorders), are more frequent with female athletes in aesthetic sports than in endurance and team sports (Torstveit & Sundgot-Borgen, 2014). Estimates of incidence of eating disorders, which can have negative, sometimes even fatal, consequences on health as well as on physical performance, reach up to 62% with female athletes and 33% with male athletes (Bonci et al., 2008). There are concerns over the negative energy balance among gymnasts in the period between 6 and 15 years of age, since there is a high risk of pathological eating disorder (Malina et al., 2013) that can manifest into a mental disorder even later in life, after the finished period of competing, due to different pressures of the environment and expected behavior. Besides the recommendations on the appropriate energy and micro nutrient sufficiency and a regular exposure to sunlight for the required vitamin D, the information on the needs of the essential omega-3 fatty acids are also important in order to avoid potential reproductive disorders in female gymnasts. The recommended daily intake of DHA during pregnancy is therefore at least 200 mg daily, but that does not mean that pregnant women are encouraged to eat fish, since most of them are contaminated, among other substances with mercury, which is a neurotoxin that especially damages the fetus (Koletzko, Cetin & Brenna, 2007). A quantitative assessment of the risk of contamination with mercury when consuming fish and the benefits due to the content of DHA that was done by the Dutch scientists showed that the negative effect of mercury on the *intelligence* quotient (IQ) is greater than the potential positive effect of DHA in the majority of fish (Zeilmaker et al., 2013). Eating habits throughout the person's entire life are equally important, since exposure to heavy metals, PCBs, and other industrial chemicals in the period of breastfeeding, childhood, and adolescence (breastmilk, eating fish) has a long-term negative effect for decades to come, including the period of pregnancy (Glynn et al., 2007). Consuming DHA dietary supplements during pregnancy has proved to be unjustified in some cognitive tests with properly fed and healthy children, which some studies that were included in previous scientific reviews did not include, e.g. the test of attention, working memory, or the precision of looking for the hidden toy (Gould, Makrides, Colombo & Smithers, 2014). One of the last studies (Shulkin et al., 2016), which examined the influence of supplementation with omega-3 fatty acids during pregnancy and breastfeeding, was based on 15 studies which included 2525 children and it concluded that EPA and DHA supplementation during pregnancy or in the period of breastfeeding improves the child's development of the nervous system. Asthma is a chronic inflammation of the respiratory tract that is also present among athletes and the nutrition of the Western world, which is based on a high content of fat, might be one of the most important risk factors (Wood, Garg & Gibson, 2011). A systematic overview of 7 observational studies, which examined the connection of asthma and consuming fish or EPA and DHA from fish oils during the time of pregnancy, revealed that consuming fish or EPA and DHA is inversely related with the development of asthma in childhood. This analysis only adds evidence to the existing literature of randomized controlled studies about the importance of consuming omega-3 fatty acids for general health, the health of pregnant women, and babies (Yang, Xun & He, 2013) as well as for reducing the incidence of asthma and respiratory infections in childhood

(Bisgaard et al., 2016). Breastmilk contains variable amounts of DHA, which depend on the diet of the nursing mother, raising the question whether consuming omega-3 fatty acids in the form of dietary supplements might only be beneficial in the event when the pregnant woman does not eat fish on a regular basis. Nursing mothers who had a vegan diet in one of the studies had a lower amount of DHA in their milk when compared with vegetarians and nursing mothers who had an omnivorous diet, but researches did not find any consequences of these differences in the growth or the neurological and intellectual development of the children, as long as their nutrition contained an appropriate intake of vitamin B12 (Sanders & Reddy, 1992). According to recent studies, the general belief is that a lower content of DHA in the breastmilk in not necessarily connected with a defective development of the fetus (Mulder, King & Innis, 2014). However, in several examples in which they could suffer a fatal lack of DHA needed for a comprehensive and long-term cognitive development, there is a consensus that pregnant women and nursing mothers should consume 200 mg of DHA (Koletzko, Cetin & Brenna, 2007), probably best in the form of a dietary supplement from a non-toxic source.

Consuming fish or omega-3 dietary supplements and cognitive abilities

Researchers conducted a randomized double-blind study of almost 3000 cardiovascular patients, aged between 60 and 80, in the period of 40 months, where one group received 400 -mg of EPA and DHA in the form of a dietary supplement from fish oils, the second group 2 g of ALA from plants, and the third and fourth group placebo, and they did not observe any positive effect on the cognitive functioning of the brain (Geleijnse, Giltay & Kromhout, 2012). On the other hand, a randomized double-blind study (Stonehouse et al., 2013) which lasted for 6 months and was conducted on 176 healthy non-smokers, aged between 18 and 45, who rarely consumed fish before the study (an intake of less than 200 mg of EPA and DHA per week), demonstrated positive effects of consuming EPA and DHA dietary supplements on certain aspects of the cognitive functioning of the brain and also showed differences in gender. In the intervention, the total intake was 170 mg of EPA and 1160 mg of DHA, which is comparable with the existing guidelines of a healthy diet that recommend eating fish rich in omega-3 fatty acids two to three times per week. The authors of the research state possible reasons for the different results of other randomized controlled studies in examining the influence of consuming omega-3 fatty acids on brain health, including the short duration of the studies in which they could not measure the significant effect, distinguishing the effects between gender, the diversity of effects that can be expected (memory, the reaction time of memory, attention, speed of processing), different amounts of intervention of EPA and DHA fats, different initial states of the participants according to the consumption of omega-3 fatty acids, etc., which could lead to inaccurate conclusions. Yurko-Mauro et al. (2010) conducted a randomized double-blind study of 485 healthy adults older than 55 years, which lasted for 2 years and in which they measured the influence of a daily supplementation of 900 mg of DHA omega-3 fatty acids. The intervention group, compared with the placebo-controlled group, showed an improvement in learning and functioning of the memory and other cognitive abilities connected with ageing. Meanwhile, Chew et al. (2015) conducted a randomized double-blind study of 4203 people with some sort of risk, e.g. developing age-related macular degeneration, where the experimental group consumed 1 g of omega-3 dietary supplement daily for 5 years (350 mg of EPA and 650 mg of DHA), and they did

not demonstrate any significant effects on cognitive health. The authors indicated that the possible reasons for the inefficient supplementation on cognitive health of the participants could be attributed to their good nutritional status and high education, the short period of intervention, and a possible late start of the intervention, since the average age of the participants was 72.7 years at the beginning of the study. Another study examined the brains with MRI twice in the period of 5 years and revealed that 3660 people older than 65 years, who in general consumed more food with omega-3 fatty acids, especially DHA, had healthier brains (Virtanen et al., 2013). A study that examined the connection between the intake of EPA and DHA and the volume of the brain, which is connected with a lower risk for dementia, included 1575 participants and showed, using MRI and various cognitive tests, that a lower amount of DHA fats in the blood is associated with a smaller volume of the brain and an impairment of cognitive functioning of the brain, even in people without clinical dementia (Tan et al., 2012). With a randomized double-blind study they confirmed for the first time the conclusions of the predecessors and, in a research that lasted for 26 weeks, with an intervention of 2.2 mg of omega-3 fatty acids from the source of fish oils, showed that consuming DHA and EPA is connected with a better cognitive functioning and a microstructural integrity of the brain of healthy older adults (Witte et al,. 2014).

The hypothesis of the effect of omega-3 fatty acids (more precisely DHA) on cognitive abilities is based on a double effect on the improved complex of reaction efficiency, namely slower fatigue, which enables a constant efficiency of motor sensations, and improving the processes of motoric sensations, leading to shorter reaction times and higher accuracy. A double-blind study (Guzmán et al., 2011) examined the influence of a 4-week intervention of consuming 3.5 g of DHA daily on the functioning of the nervous and motor system of 34 professional female football players. The test instrument was a part of the ASDE driver test and consisted of a series of psychological tests to assess psychomotor and perceptual-motor skills. The test examined the response to visual and auditory stimuli and registered responses. The researchers discovered that the experimental group had better results when it came to complex reaction time, accuracy, and efficiency (a more appropriate selection of technical and tactical solutions). The authors conclude that the reliability of the study is connected with the homogeneity of the sample and the control of the intake of macronutrients between the two groups, but there are justified concerns about the potentially inadequate nutrition of the female football players, since their 3050 calories per day consisted of 16% of protein, 44% of fat, and only 40% of carbohydrates. Numerous researchers examined the potential correlation between the consumption of dietary supplements EPA and DHA and the effect on cognitive abilities and mood, which is the basis for consistently successful trainings and performances in various sport disciplines. With some studies (Fontani, Lodi, Migliorini & Corradeschi, 2009), but not all (Jackson, Reay, Scholey & Kennedy, 2012), researchers have reported on the improvement of the learning curve or, in other words, visual attention and speed of information processing. Fontani et al. (2009) took a sample of martial arts athletes to measure the influence of consuming 2.25 g of omega-3 fatty acids on maintaining alertness and attentiveness and they discovered an improvement in the experimental group when it came to reaction time and mood. In one double-blind cross-over study that included 13 young adults, Bauer et al. (2014) compared the influence of DHA (417 mg of DHA and 159 mg of EPA daily) with the influence of EPA (590 mg of EPA and 137 mg of DHA daily) on the functioning of

the nervous system while executing cognitive tasks (STROOP, SWM, and SUCCAB tests) and discovered a higher efficiency of EPA in visual neural recovery and the choice of reaction times.

Some gymnasts face the most frequent neurobehavioral disorder from early childhood on; the attention deficit hyperactivity disorder or ADHD, but only a few ever speak of it. *(the fourfold American Olympic champion Simone Biles (Turner, 2016) and the twofold British Olympic silver medalist in competitive gymnastics Louis Smith (BBC, 2016) also suffer from ADHD)*. Healthcare professions usually solve the problem of restlessness, problems with attention and monitoring heart rate, and in some cases hyperactivity, which results in problems with learning, discipline, anxiety, and depression, by prescribing pills that have a number of perceived side effects. Inappropriate nutrition, in connection with hereditary and environmental factors, presents an important risk factor in preventing or controlling ADHD (Curatolo, D'Agati & Moavero, 2010). Authors Howard et al. (2011) connect ADHD with the nutrition of the Western world, which is characterized by micronutrient insufficiency and an excess of energy density and is full of highly processed food containing saturated fats, salt, and sugar. On the other hand, an overview of scientific effects of omega-3 fatty acids on ADHD showed that the supplementation with EPA and DHA in the period of 3 to 4 months significantly improved ADHD symptoms, especially in connection with GLA omega-6 fatty acids (Transler, Eilander, Mitchell & van de Meer, 2010). An analysis of 10 randomized, placebo-controlled studies, which included 699 children, showed "only" a moderate efficiency in comparison with the currently used pills, but the authors do emphasize a relatively innocuous side effect profile of omega-3 fatty acids (Bloch & Qawasmi, 2011). Another analysis of 24 randomized controlled studies (Cooper, Tye, Kuntsi, Vassos & Asherson, 2015) that examined the effect of supplementation of omega-3 fatty acids on cognitive abilities or ADHD, failed to prove the eligibility of the intervention, despite some individual studies with formulations with more EPA (perhaps because of lower concentrations of omega-3 fatty acids in plasma and red blood cells in children and adolescents with ADHD). This was most likely due to the incompatibility of various components of cognitive abilities and the tests that were used. The authors therefore warn that in practice there is a serious problem, due to the unwarranted advertising of the positive influence of consuming omega-3 fatty acids on cognitive abilities, since the claims about the potential benefits on cognitive abilities should be limited only to certain conditions.

Consuming fish or omega-3 dietary supplements and systemic inflammations, DOMS, and mood

Muldoon et al. (2015) conducted a randomized controlled study with 261 healthy adults, aged 30 to 54, examining the influence of 1400 mg of EPA and DHA (1000 mg of EPA and 400 mg of DHA) from fish oils in the form of a dietary supplement on the potential reduction of systemic inflammations. In a period of 18 weeks, the researchers compared the intervention group and the placebo-controlled group and found no reduction of systemic inflammation, which was measured by general markers of inflammation (CRP, IL-6, IL-1β, IL-8, and TNF-α), even though supplementation brought a 64% increase in EPA and DHA in the red blood cells. Consuming EPA and DHA in the form of a dietary supplement did result in a better "condition" of the blood, but it did not reduce systemic inflammation, most likely because the participants in the study were healthy. The CRP of 75% of the participants was under 2 ng/mL before the beginning of the study, but additional analysis of the group with the initial CRP above 2 ng/mL or IL-6

above the reference values also showed no change in the markers of systemic inflammation. In the modern world, two-thirds of adults are overweight and that is why they usually have abnormal markers pointing to systemic inflammations. Eating animal source foods, such as dairy products, meat, eggs, and vegetable oils, increases inflammations in the body. Even a single high-fat meal may increase inflammations in the body within a couple of hours, which can mostly be seen in arteries that are more stiff and narrowed (Bui et al., 2010; Vogel, Corretti & Plotnick, 2000), and can contribute to chronic inflammatory diseases of the respiratory system (Rosenkranz, Townsend, Steffens & Harms, 2010).

The next potential benefit of consuming omega-3 fatty acids for gymnasts is the influence on the reduction of inflammatory processes in the body due to an individual exercise or exercise program, which can further reduce delayed onset muscle soreness (DOMS). One of the randomized, double-blind, placebo-controlled studies that was conducted on 45 healthy men, who were not included in any exercise program prior to the study, examined the influence of consuming 1.8 g of omega-3 fatty acids in the form of a dietary supplement on the inflammatory processes during an eccentric exercise *(numerous gymnastic elements include rotations around the horizontal or linear axis and are executed with eccentric muscle contractions of the legs and arms)* which was tested before the exercise, immediately after it, 24 hours later, and 48 hours later. The research team found that the 4-week intervention with omega-3 fatty acids, in connection with the eccentric exercise, was efficient in reducing the inflammatory markers (Tartibian, Maleki & Abbasi, 2011). It is important for gymnasts that the potential reduction of inflammatory processes is also connected with reducing DOMS. DiLorenzo, Drager, and Rankin (2016) examined the effect of a prior consumption of 2 g of DHA that lasted for 28 days before the beginning of a training period that lasted for 17 days and was tested on 41 untrained men, which included an eccentric exercise for the strength of flexors in the elbow, while the researchers examined the progress of isometric strength and flexibility as well as DOMS after 1, 2, 3, 4, 7, 12, and 17 days. The research showed encouraging results of consuming DHA on the reduction of certain markers of muscle damage throughout the 17 days of executing the eccentric exercise for building strength. Gray, Chappell, Jenkinson, Thies, and Gray (2014) came to the same conclusions, namely that some (not all) markers of oxidative stress did improve in the randomized, double-blind, placebo-controlled study that lasted for 6 weeks and included a single exercise (extension of the knee) in eccentric conditions. A similar assessment was also given by researchers (Corder, Newsham, McDaniel, Ezekiel & Weiss, 2016) who conducted a randomized, placebo-controlled study, which included 14 women (the placebo group consisted of 13 women) and measured the influence on the inflammatory processes and DOMS with an intervention of 3 g of DHA from seaweed 7 days before and 2 days after an eccentric exercise for strength. DOMS in the experimental group was reduced by 23%, while numerous participants of the placebo group could not extend their elbow even 48 hours after the eccentric exercise. Authors conclude that intervention with a DHA dietary supplement ensures a better preservation of the amplitude around the joint in days of strenuous eccentric trainings and can be efficient in reducing DOMS and muscles stiffness and when introducing a new training program for the athlete, which can have a positive influence on the process of adapting to the training. One of the most representative studies was a randomized, double-blind, placebo-controlled study which was done by Atashak et al. (2013). They examined 20 young athletes and measured the effect

of consuming 900 mg of EPA and DHA daily on the level of oxidative stress, muscle damage, and inflammatory markers in a single high-intensity training for building strength (a scientifically already used protocol, i.e. circuit training with 3 exercises for strength, 4 series of 7 to 10 repetitions until failure, and 3-minute breaks) and measured the improvement in biomarkers of inflammations and muscle damages, with which they have proven a potential effectiveness of consuming omega-3 fatty acids in minimizing oxidative injuries and systemic inflammation due to a single high-intensity training for building strength, which included an eccentric function. On the other hand, another study (Bloomer et al., 2009) failed to show a positive influence of consuming omega-3 fatty acids on the reduction of inflammatory processes or DOMS, but this does not lessen the value of previous results, since the study was conducted on an unrepresentative training protocol that did not cause an eccentric contraction, e.g. a 60-minute walk uphill on the treadmill with additional burden. One of the scientific overviews that examined the influence of various nutritional interventions on DOMS, among other also with omega-3 fatty acids, showed that consuming omega-3 fatty acids in eccentric contractions is related more to the oxidative stress for reducing DOMS (Kim and Lee, 2014). In sports literature, omega-3 fatty acids have shown efficiency in reducing processes of inflammation and muscle damage and in deformation of red blood cells and metabolism during exercise, but the results of the studies of the intervention with omega-3 fatty acids in meta-analyses are often inconsistent due to inadequate study design. Jeromson, Gallagher, Galloway, and Lee Hamilton (2015) believe that the inappropriate ratio of omega n-6/n-3 in the dietary pattern is one of the main variables that can reduce the effect of intervention with omega-3 fatty acids.

One of the main arguments for recommending a regular consumption of fish or omega-3 fatty acids (EPA and DHA) in the form of a dietary supplement is that EPA and DHA are vital for the functioning of the brain and proper mood state. An overview of 13 randomized, placebo-controlled studies that were conducted on 731 participants and examined the impact of the efficiency of EPA and DHA omega-3 fatty acids on the level of depression did not show any significant benefits of prescribing omega-3 fatty acids for treating depression (Bloch and Hannestad, 2012). On the other hand, the cross-over and intervention studies have shown that a vegan diet, or even avoiding meat and fish for 14 days, has a significantly positive effect on the mood state, stress, and depression, even though vegans had a lower level of EPA and DHA in the blood. This is most likely due to avoiding high-protein (less arachidonic acid, which is the precursor of inflammatory hormones, and more polyunsaturated fats) and high-fat animal source foods and due to a higher intake of antioxidants, which significantly contributes to a lower oxidative stress (Beezhold, Radnitz, Rinne & DiMatteo, 2015).

Consuming fish or omega-3 dietary supplements and physical performance

Some researchers have connected the consumption of EPA and DHA fatty acids in the form of a dietary supplement from fish oil with a reduction in markers of systemic inflammations as a consequence of an immune response to exercise (Andrade, Ribeiro, Bozza, Costa Rosa & Tavares do Carmo, 2007), while many researchers failed to show the influence of consuming omega-3 fatty acids on the performance or a quicker recovery in healthy adults or well-trained athletes of team sports (Bortolotti, Tappy & Scheiter, 2007; Buckley, Burgess, Murphy & Howe, 2009; Raastad, Høstmark & Strømme, 1997). One research (Rodacki et al., 2012)

randomly divided 45 healthy women (65 years old) into 3 groups (exercise for strength; exercise for strength and EPA and DHA; EPA and DHA). The supplemented groups consumed 400 mg of EPA and 300 mg of DHA daily, 60 days before the beginning of the training (90 days altogether), which included exercises for strength three times a week in a period of 12 weeks. The research showed better results in muscle strength and functional capacity in the group that exercised and, in addition, consumed omega-3 fatty acids. Body weight remained unchanged in both groups after 12 weeks, which suggests the influence of omega-3 fatty acids on additional improvement of muscle activation and, consequently, on muscle strength. Walser, Giordano, and Stebbins (2006) conducted a study of 7 healthy people who were consuming 2 g of DHA and 3 g of EPA for 6 weeks and they measured an increase in brachial artery blood flow and conductance during a 90-second submaximal rhythmic squeezing of the fist (30% of maximal strength of the squeeze), while the placebo group did not show this effect. Clark, Monahan, and Drew (2016) conducted a study of 14 healthy young people (25 years old) and 15 older people (64 years old) and measured the impact of consuming 3.6 g of EPA and DHA for 12 weeks with a 15-second squeeze of the fist at 10%, 30%, 50%, and 70% of maximum conscious contraction and discovered that both teams of young and old participants who enjoyed the omega-3 fatty acids in the form of dietary supplements had a lower diastolic and mean arterial blood pressure. Omega-3 fatty acids additionally improve the blood flow during exercise, reducing the deformation of red blood cells, which theoretically increases the flow of oxygen and nutrients into the trained muscle. Tiryaki-Sönmez, Schoenfeld, and Vatansever-Ozen (2011) reviewed the studies that examined the influence of a combined consumption of omega-3 fatty acids on body composition and physical ability and they concluded that a generalization of scientific evidence about the potential synergistic benefits is problematic due to the limitations of the study designs. Mickleborough (2013) was faced with inconsistent results in the field of intervention with omega-3 fatty acids and physical performance when he was trying to determine the optimal intake of omega-3 fatty acids that would maximize the ratio between benefits and risks and he came to the conclusion that the reasons for such diverse results, which make it impossible to determine the final recommendations, are connected with the heterogeneity of the participants, the intensity and duration of the examined exercise or training, different types, amounts, and duration of the intervention with EPA and DHA dietary supplements, and the interval of duration of measuring the selected biomarkers of the studies. One of the last overviews of literature (Da Boit, Hunter & Gray, 2017) that examined the potential implication of consuming omega-3 fatty acids on physical ability showed that the majority of research focuses on measuring the increase in metabolic capacity, the reduction of delayed muscle pain and fatigue, the improvement in hypertrophy, recovery, and the immune system, and the reduction of oxidative stress. Based on the inconsistency of the majority of research, the authors conclude that the supplementation with omega-3 fatty acids for the needs of physical ability is potentially justified for athletes with asthma and in sport disciplines in which the primary motor ability that determines effectiveness is connected with strength, which can therefore also be applied to gymnasts. Even though today the mechanism of action is relatively well explained, the reliable implication of consuming 1–4 g of omega-3 fatty acids in the form of a dietary supplement for the needs of gymnasts requires research in various situations during trainings and competitions.

Consuming fish or omega-3 dietary supplements and body composition

The mechanism that theoretically connects consuming omega-3 fatty acids with losing body fat is connected with the improvement of insulin sensitivity, which results in an improved use of stored fat reserves. Numerous studies which have proven the benefits of consuming omega-3 fatty acids on body composition may be problematic when applying them to gymnasts, since they included overweight or even clinically obese ordinary people who might have a particular insulin resistance. The first randomized controlled study (Thorsdottir et al., 2007), which included 324 people (aged 20 to 40 years) that were divided into 4 groups (the control group; consuming 150 g of lean fish three times a week; consuming 150 g of fatty fish three times a week; 1300 mg of EPA and DHA from fish oils), examined the influence of omega-3 fatty acids on the loss of excess body weight in a period of 8 weeks by prescribing the same isocaloric intake and ratio between the nutrients (30% of fat, 50% of carbohydrates, 20% of protein) and a similar amount of exercise and found that men who consumed fish or dietary supplements from fish oil lost one kilogram more than the control group. When it came to women, the researchers did not find any differences among the four groups with different diets. Similar results, but this time with women, were obtained by Noreen et al. (2010), who, in addition to weight loss, also found a lower amount of subcutaneous fat, an increase in lean muscle mass, and a reduction of cortisol in the saliva in a period of 6 weeks. One of the most relevant studies was conducted by the researchers Munro and Garg (2012), which was a randomized, double-blind, placebo-controlled study that included 29 clinically obese people (aged 18 to 60 years) and measured the effect of consuming 420 mg of EPA and 1620 mg of DHA on the loss of excess body weight with a low-energy diet and a low intake of fat (720 calories, 40% of protein, 16% of fat, 40% of carbohydrates) in a period of 14 weeks, but they failed to confirm the eligibility of consuming EPA and DHA for the loss of excess body weight. One of the last overviews of 21 randomized, placebo-controlled studies that examined the influence of EPA and DHA from fish oil on overweight and obese people showed that current evidence does not support a weight-loss role of omega-3 fatty acids, but individuals can experience a reduction of abdominal fat and the waist-hip ratio, especially when they combine the intervention with omega-3 fatty acids with a change of lifestyle (Du, Jin, Fang & Su, 2015). The latter could be important for gymnasts who wish to lose excess fat while maintaining body weight (muscle and bone mass), with which they consequently maintain physical abilities and most likely also the immune system. Many differences between researchers point to the fact that a short-term influence of consuming omega-3 fatty acids on the control of body weight most likely does not represent a promising field of research so it might be better to direct this research into examining long-term supporting effects of consuming omega-3 fatty acids on the athletes' body composition, their immune system, and a successful recovery.

Every day, more and more young people and athletes turn to a vegetarian diet, usually because of the assumed impact on preventing chronic diseases, improving the immune system, offering a more efficient recovery after training, and enabling an easier control of body weight, and perhaps also out of ethical reasons. In one research (Farmer, Larson, Fulgoni, Rainville & Liepa, 2011) vegetarian diets were proven to be nutritionally adequate, even with a calorie restriction of 500 calories less than the estimated energy requirements, and can be recommended for control of body weight without reservations. In one randomized controlled study (Turner-McGrievy, Davidson, Wingard, Wilcox, & Frongillo, 2015) authors compared the efficiency of

different plant-based diets (vegan, vegetarian, pesco-vegetarian, half-vegetarian diet) with an omnivorous diet and discovered that plant-based diets, especially the vegan diet, are most affective in losing excess body weight. Katz and Meller (2015) carried out an overview of scientific studies of the most common diets and concluded that the majority of scientific evidence strongly connects a well-planned vegan diet with health, a successful control of body weight, and prevention against systemic inflammations and chronic diseases. On the basis of the index of healthy nutrition and the assessment of a Mediterranean diet conducted on 1475 people (104 vegans, 573 vegetarians, 498 half-vegetarians, 145 pesco-vegetarians, 155 people with an omnivorous diet), Clarys et al. (2014) assessed that the vegan diet is the healthiest (related to body weight and nutritional adequacy), while the omnivorous diet received the lowest assessment of the two indicators of a quality nutrition. Not long ago, the Academy of Nutrition and Dietetics (AND) reiterated its position from the year 2009 about the adequacy of vegetarian diets for different groups of people and stated that a well-planned vegetarian diet, including the vegan diet, is healthy and nutritionally adequate and appropriate no matter the period of a person's life, even during pregnancy and breastfeeding, during childhood and adolescence and also for athletes (Melina, Craig & Levin, 2016).

On the other hand, Chen et al. (2009) write that, when talking about gymnasts and the reduction of unnecessary fat or the control of body composition while simultaneously maintaining or even improving the optimal level of physical abilities, this is a long-term process, since the latter must also include control over the amount of trainings. The case study of an Olympic gold medalist was based on the moto "less eating, more training" and turned out to be successful. A short-term diet (1600 calories, 68% of carbohydrates, 20% of protein, and 12% of fat) for achieving momentary loss of excess fat was, according to the authors, energy-efficient, did not include dairy products (35%–70% of calories came from fat), but did include vitamin and mineral dietary supplements. The gymnast lost 356 g of fat from the total of 840 g of weight loss, while the rest of the weight loss was due to the loss of muscle mass, which in the end fortunately did not have a negative impact on the performance. The short-term influence of the intervention in this case study, especially because the article does not mention BMI (or the height through which it would be measured) or body composition, cannot be generally applied to the long-term needs of other gymnasts who are faced with permanent control of optimal body weight, especially because the authors did not measure the numerous micronutrients, among others also the intake of omega-3 fatty acids, or potential consequences of a possible deficiency. However, this could present a basis for research in future studies that would include a larger number of gymnasts.

CONCLUSIONS

- Studies about the benefits of consuming omega-3 fatty acids (ALA, EPA, and DHA) on general human health as well as the potential risk of excessive intake (when EPA and DHA exceed 1 g daily) show that the ratio forms a U-shaped curve. Here we must emphasize that there exists no scientific evidence that would confirm that consuming EPA and DHA can compensate for an unhealthy diet or significantly improve our health.
- Numerous analyses of studies of adults, which measured the effect of omega-3 fatty acids on the primary and secondary prevention of cardiovascular disease, showed that the supplementation with EPA and DHA is not connected with a lower mortality rate due to any reason. A lower incidence of cardiovascular disease is most likely the result of other dietary

factors (in general a healthier eating pattern) and a lifestyle that is a result of people who are more aware and also eat fish. Throughout their gymnastic development, gymnasts require more education by qualified professionals about a well-planned and healthy diet and about monitoring the implementation of concrete guidelines through the strenuous rhythm of trainings, the yearly calendar with competitions, and the competitive career in general.

- It is difficult to uncritically imply the influence of consuming omega-3 fatty acids on cognitive abilities, which include a very broad and complex field of numerous neurological processes, for the needs of gymnasts, since there is currently a lack of research carried out with representative tests. Some studies have shown a greater direct applicability of the intervention with EPA and DHA in a potentially more frequent occurrence among gymnasts, i.e. ADHD, especially in combination with a healthy diet, which could be relevant since most of the medication that is used for ADHD carries numerous side effects (Gelperin, 2006).
- The evidence about the effects of consuming omega-3 fatty acids, especially EPA and DHA, on systemic and local inflammations and DOMS in eccentric contractions (exercise or training) is much more consistent in comparison with other muscle contractions. EPA and DHA from a verified manufacturer might present one of the permitted and safe dietary strategies if a gymnast uses all other known and permitted ways for an efficient recovery during their training rhythm and workout program, but only as part of a special assessment of needs by the coaching team, especially by a qualified professional from the field of ordinary diet and sports nutrition.
- An overview of studies that examined the influence of EPA and DHA on overweight and obese people showed that the current evidence does not support a weight-loss role of omega-3 fatty acids. On the other hand, researchers for vegetarian diets have proven that they are nutritionally adequate even with calorie restrictions and can be undoubtedly recommended to gymnasts for a successful control of body weight. Furthermore, AND reiterated that a well-planned and supervised vegetarian diet, including the vegan diet, is healthy and nutritionally adequate and appropriate no matter the period of a person's life, even during pregnancy, breastfeeding, during childhood and adolescence and also for athletes.
- Gymnasts who are vegetarians and do not consume fish or dietary supplements from various reasons (a type of vegetarianism, allergies to a specific source of omega-3 fatty acids) are recommended to either double their intake of ALA or to consume at least 200–400 mg of EPA and DHA in the form of a dietary supplement in order to avoid potential inadequate ability to convert ALA into EPA and DHA or in the case of greater needs.

Based on the majority of credible scientific evidence we can firmly conclude that a successful control of body weight, efficient trainings and recovery, and successful performances of gymnasts that have no long-term negative effects on health are based on a healthy diet, which is based on a well-structured diet that consists mainly (but not necessarily solely) of plants (e.g. starch and non-starch vegetables, fruits, nuts and seeds) and which, in its unrefined form, is also low in fat. When it comes to the optimal healthy diet of gymnasts we must also add to this 1–2 spoons of a representative intake of ALA (e.g. from flaxseeds) and, to be on safe side, also 200–400 mg of EPA and DHA in the form of a dietary supplement (fish oil or marine microalgae). It is of vital importance that the dietary supplement is strictly an addition to the ordinary diet and that is does not include any contaminants. This satisfies the two principles, i.e. the nutritional adequacy of

EPA and DHA for the needs of various body systems and their functions and the minimal exposure to industrial contamination, which could nullify the benefits of the intake of omega-3 fatty acids.

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ELITE FEMALE GYMNASTS AT TWO OLYMPIC GAMES – QUALITY OR LUCK?

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Original article

Abstract

Relatively small number of gymnasts participate at the Olympic Games and even smaller number participates at Olympic Games consecutively, due to numerous different reasons. Therefore, this paper aims are: 1) to determine the number of female gymnasts who participated in the C-I competition at Olympic Games held in 2012 and at Olympic Games held in 2016; 2) to determine characteristics and differences in results of consecutive participants at these two Olympic Games; 3) to determine differences between consecutive participants and other competitors at the afore defined competitions. It was found that 25 female gymnasts participated at two consecutive Olympic Games. From one to another Olympic Games, consecutive participants have numerically increase all scores; significantly increased Execution and Final Scores on the uneven bars; significantly decrease Execution and Final Score on the balance beam. Compared to other gymnasts from the 2012 and 2016 Olympic Games, consecutive participants had numerically higher values in all variables, but only some of them have been determined as significantly different. Consecutive participants confirmed the possibility of continuous quality of skills development in mid 20s.

Keywords: *consecutive participants, C-I competition, 2012-2016 Olympic Games, ANOVA.*

INTRODUCTION

Being an Olympic athlete is a dream of many people and the aim of most elite athletes. Different studies quote somewhat different time which is needed in order to achieve Olympic quality: Ericsson, Charness, Feltovich and Hoffman (2006) and Gladwell (2009) state that it takes around 10 000 working hours to achieve the Olympic quality; Arkaev and Suchilin (2009) state that it takes at least 8-10 years to reach top artistic gymnastics quality in girls and 10-12 years in boys; Gibbons et al. (2002) reported that it takes 11 to 13 years of practice in order to reach elite performances; Tucker (2011) believes that superior performances can be achieved within a significantly shorter period of time.

It is often heard that in order to reach high levels of ability, a person needs to have an innate potential called *talent*. Talent term for an aptitude, a special gift of above-average ability in a certain area, here in the area of sport motor actions, and for the person possessing these abilities. In regard to sport, three forms of talent can be differentiated: general motor talent (high motor learning ability, good motor ability,

broad repertoire of movements), sport talent (extraordinary ability and readiness to deliver sport performances), and sport-specific talent (existence of specific physical and psychological prerequisites necessary for delivering excellent performances in a certain sport discipline; Haag and Haag, 2003). Howe, Davidson and Sloboda (1998) analysed positive and negative evidence and arguments about talent. They concluded that early experiences, preferences, opportunities, habits, training and practice are the real determinants of excellence. When those are controlled, there is a little evidence of individual differences in the learning speed and quality.

In 1985, Bloom provided his opinion on the importance of talent in relation to other factors which are key in achieving the Olympic quality: „…no matter what are the initial characteristics of the individuals, unless there is a long and intensive process of encouragement, nurturance, education, training, the individuals will not attain extreme levels of capability in the particular fields."

Regardless of which theory we accept, all of them have one fact in common and that is that there are no "shortcuts" in achieving world-class performances. What is more, it is a long-term and complex process.

In the case of artistic gymnastics, this long-term process should be planned in accordance with the international gymnastics evolution tendencies and the anticipation of the sport's technical development pursuant to the changes which occur in the Code of Points (CoP) every four years (Arkaev, 1997; Rozin, 1997; according to Donti, Donti, & Theodorakou, 2014). Since the 70s, it has been pointed out that there are no unique methods of teaching and training in gymnastics (Živčić, 2000). Nevertheless, all applied methodical procedures aim to achieve the quality of the performance.

The complexity of the process of achieving an Olympic level in gymnastics is presented in the review article by Malina et al. (2013). They reported that training loads and sequencing of training activities in artistic gymnastics vary among individuals with regard to their age, competitive level, season and coach. The previous study show that: 1) the average time of training (reported by gymnasts at major championships) is approximately 30 hours per week. They state that the USA Gymnastics proposed the „optimal plan" for the training of elite senior US female gymnasts. The plan included two daily sessions (morning 2-3 hours, afternoon 3-4 hours) 6 days a week; 2) time of training overlaps in females and males and increases with age and level of competition; 3) the objective criteria for determining the intensity of training was not found; 3) the specific training activities (warm-up, stretching, strength training, instruction and repetition of specific skills and routine, rest between repetitions, dance, and choreography, etc.) are not usually reported; 4) a little attention is paid to the sex of gymnasts. The authors concluded that gymnastics training is more complex and includes more factors than just hours of training per week or number of repetitions. Furthermore, although this report was made in 2013, they concluded that reported information may not be representative for the elite gymnasts today since gymnasts face increasing demands at every new Olympic Cycle.

In order to achieve top results, today's gymnasts have to possess not only a high level of special physical qualities, perfect technique and will power, but also high work capacity and enthusiasm (Arkaev & Suchilin, 2009). From their initial training and during the process of achieving the Olympic level, CoP changes 2 to 3 times causing significant redirecting and change of content and the structure of most segments in the gymnasts' training process 2-3 times. All those changes within training do not only refer to the decision on what the gymnasts should learn, but also on how they should learn it in order to be

successful after 6 – 8 years of training when it is time to win or lose (Donti, Donti, & Theodorakou, 2014). In order to optimally use their biological chances and successfully compete in their first (and, probably, the last) Olympic Games (OG), girls at the age of 14 must have mastered the arsenal of world level exercises in gymnastics, so that, over the next two years, they can basically "catch up" at the competitions and training sessions, and meet the puberty period fully equipped (Arkaev & Suchilin, 2009).

Due to all those changes, gymnasts' training can often be risky and too demanding. The capabilities of gymnasts' anthropological aspects are pushed in order to reach the maximum. Such training very often leads to injuries or „burning out". Consequently, gymnasts, often leave the sport before they are old enough to compete internationally (at the age of 16). From the authors' experience, if they "survive" the whole process of training, most female gymnasts, in particular All-Around Competitors, end their careers before their twenties and after having competed at one OG.

According to the current regulations, female gymnasts have the right to participate in the Olympic Games when they are 16 years old (as a part of a team; Federation Internationale de Gymnastique, 2016).

In Women's Artistic Gymnastics (WAG), a maximum of 98 gymnasts have the right to participate at OG: 1) 96 gymnasts who achieve their participation right as a) a part of one of 12 qualified teams; b) based on an individual All-Around result from the World Championship (WC) that takes place one year before the OG (first 24 ranked); c) as medal winners (from the WC that takes place one year before the OG). Additional two gymnasts refer to: a) 1 gymnast who does not qualify for the OG in the qualifying competitions based on her individual or team result, but who comes from a country where gymnastics is not developed as a sport; b) 1 (the best) gymnast from the country which is organizing the Olympic Games and who does not ensure participation through the qualification system (http://corporate.olympics.com.au/files/dmfile/FIG_Gymnastics_April2011.pdf.)

After having qualified for the OG and taking into account structural complexity of this sport and the aspiration to achieve gymnasts' maximum in a relatively short career, the issue of OG competing tactics becomes extremely important (Arkaev & Suchilin, 2009). Regardless the fact that almost solely All-Around female gymnasts qualify for the OG, they are not obligated to compete on all apparatuses at OG. This rule is mostly used by: 1) competitors who accomplish their aim just by participating at OG; 2) competitors who believe that their All-Around result, as opposed to their result on a single apparatus, is not good enough for the final competition.

Based on the aforementioned, the authors posed the problem of this paper: to analyse characteristics of female gymnasts who manage to be consecutive participants at two OG. Accordingly, this paper aims to: 1) determine the number (percentage) of female competitors who competed at two successive OGs; 2) determine exercising quality of female gymnasts who participated at two consecutive OGs; 3) determine differences between consecutive participants and other competitors from OG2012 and OG2016.

METHODS

The sample included all the elite senior female gymnasts who participated in the C-I competitions at OG held in 2012 (OG2012; N_1=97) and 2016 (OG2016; N_2=98). The sample has been divided into two groups depending on the number of participations at OG (female gymnasts who participated at two consecutive OGs (FG2×OG) and female gymnasts who participated only at one OG (FG1×OG). At OG2012 group of FG2×OG (N=25) was

21.04±4.93 years old, while at OG2016 they were 25.07±4.93 years old. Female gymnasts who participated only at OG2012 (N=72) were 20.23±3.80 years old, while ones that participated only at OG2016 (N=73) were 19.45±3.13 years old.

Average age of FG2×OG without Oksana Chusovitina (who was vault finalist at OG2012 and OG2016, and whose age make her an outlier not only in artistic gymnastics but in most elite sports (her participation at the Summer OG in Rio made her the oldest female gymnast in Olympic history) was 20.45±3.83 years old, while at OG2016 they were 24.22±3.73 years old.

The variable sample is represented by a set of *Vault Difficulty Scores (VTDS)*, *Vault Execution Scores (VTES), Vault Final Scores (VTFS), Uneven Bars Difficulty Scores (UBDS)*, *Uneven Bars Execution Scores (UBES), Uneven Bars Final Scores (UBFS), Balance Beam Difficulty Scores (BBDS)*, *Balance Beam Execution Scores (BBES), Balance Beam Final Scores (BBFS), Floor Difficulty Scores (FXDS)*, *Floor Execution Scores (FXES)* and *Floor Final Scores (FXFS)* obtained at the Qualification Competition (C-I) at OG2012 and at OG2016 by the apparatus competitors, and *All-Around Score (AA)* obtained at the same competitions by the All-around competitors.

The values of the mentioned scores have been retrieved from the specialized web site for gymnastics results (www.gymnasticsresults.com, accessed on the 18th of October 2016.).

Previous studies presented detailed descriptive parameters of analyzed variables for the same competitions (Massida & Calo, 2012; Leskošek, Čuk, & Bučar, 2013; Atiković et al., 2014; Erceg, Delaš Kalinski, & Milić, 2014) as well as generally satisfactory metric characteristics of those scores (Bučar, Čuk, Pajek, Karácsony, & Leskošek, 2012; Bučar Pajek, Čuk, Pajek, Kovač, & Leskošek, 2013).

Data analysis included calculations of Mean±Standard deviations. One Way repeated measures ANOVA was used to determine differences between the performances of FG2×OG. One Way ANOVA for independent samples was used to analyze differences between FG1×OG and FG2×OG (from the OG2012 and from the OG2016). Data was considered significant if $p<.05$. All calculations were performed using software package Statistica 12.0. (StatSoft, Tulsa, Oklahoma, USA).

RESULTS

Competitive tactics of FG2×OG, at both Olympic Games, is shown in Figure 1.

Although it is a multi-structural sport and there is a complex system of qualification for the OG, the largest number of FG2×OG (on both OG) competed at all four apparatuses. At OG2012, 16 of 25 FG2×OG were All-Around competitors and 9 were Apparatus competitors. At OG2016, 14 of 25 FG2×OG were All-Around competitors and 11 were Apparatus competitors. The change in the tactics for FG2×OG can be observed in the number of those who have competed on only one apparatus. At OG2012, the total number of FG2×OG who competed at only one apparatus was 1, while at OG2016 were 11 FG2×OG who competed at only one apparatus (43% of all FG2×OG).

Exercising characteristics and differences for FG2×OG are shown in Table 1.

The analysis determined that a total number of 25 female gymnasts had the experience of previous OG. Most of the consecutive Apparatus Competitors on the OG2012 competed floor, while the lowest frequency of consecutive Apparatus Competitors has been determined at the uneven bars. At OG2016 the highest

frequency of consecutive Apparatus Competitors has been determined at the balance beam and the lowest at the floor. Compared to their results from the OG2012, at OG2016 Apparatus Competitors FG2×OG achieved higher values in VTES, UBDS, UBES, UBFS, FXDS, FXES, FXFS variables, and lower values in VTFS, BBDS, BBES, and BBFS. However, numerically significant differences were found only in the values of UBES, UBFS, BBES and BBFS.

Comparison of the results achieved by All-Around competitors FG2×OG at OG2012 and at OG2016 resulted in numerically slightly higher AA value at the latter.

The characteristics and the differences in relation to FG2×OG and FG1×OG (from the OG2012 and the OG2016) are shown in Table 2.

Table 1
Differences of FG2×OG performance at the OG2012 and at the OG2016.

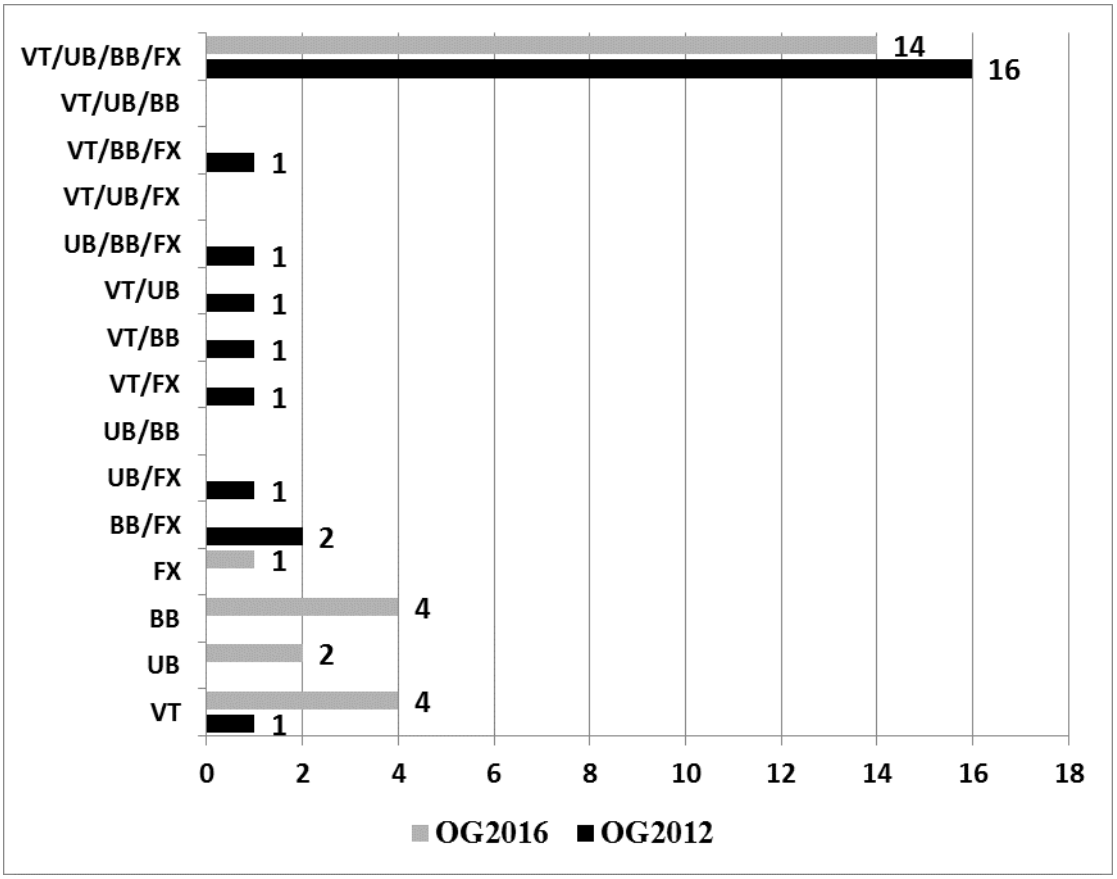
		2012		2016	ANOVA		
	N_1	M±SD	N_2	M±SD	F	p	η^2
VTDS	6*	6.08±0.45	15	5.47±1.32	1.50	0.27	0.23
VTES		8.51±0.60		8.79±0.88	0.05	0.84	0.01
VTFS	18	14.42±0.91		14.39±1.63	1.18	0.30	0.09
UBDS	17	5.87±0.62	15	6.60±2.21	1.65	0.22	0.12
UBES		8.14±0.36		8.53±0.39	28.55	<0.01	0.70
UBFS		14.01±0.92		14.59±0.81	23.27	<0.01	0.66
BBDS	19	5.78±0.44	16	5.75±0.44	0.75	0.40	0.05
BBES		8.11±0.62		7.86±0.55	5.60	0.03	0.27
BBFS		13.89±0.97		13.61±0.83	4.92	0.04	0.25
FXDS	20	5.50±0.49	12	5.63±0.59	0.27	0.61	0.02
FXES		8.11±0.66		8.21±0.49	0.06	0.81	0.01
FXFS		13.56±1.04		13.82±1.01	0.09	0.77	0.01
AA	16	56.02±2.76	14	56.48±2.50	0.14	0.71	0.02

Legend: N_1 – number of FG2×OG at the OG2012, N_2 – number of FG2×OG at the OG2016, M±SD – Mean value ± Standard deviation; ANOVA - One Way repeated measures ANOVA was used: F – F value, p – p value, η^2 – effect size, (partial) eta squared, VTDS - Vault Difficulty Score of Apparatus competitors, VTES - Vault Execution Score of Apparatus competitors, VTFS - Vault Final Score of Apparatus competitors, UBDS - Uneven Bars Difficulty Score of Apparatus competitors, UBES - Uneven Bars Execution Score of Apparatus competitors, UBFS - Uneven Bars Final Score of Apparatus competitors, BBDS - Balance Beam Difficulty Score of Apparatus competitors, BBES - Balance Beam Execution Score of Apparatus competitors, BBFS - Balance Beam Final Score of Apparatus competitors, FXDS - Floor Difficulty Scores of Apparatus competitors, FXES - Floor Execution Score of Apparatus competitors, FXFS - Floor Final Scores of Apparatus competitors, AA – All-Around Score of All-Around competitors, *For the FG2xOG the OG 2012 data records, included vaules of the VTDS, VTES and the VTFS, while for all the other competitors it indicated only values of the VTFS

Table 2
Differences between the FG2×OG and FG1×OG performances.

				2012			
		FG1×OG		FG2×OG			
	N_1	M±SD	N_2	M±SD	F	p	η^2
VTDS	12	5.63±0.74	6	6.08±0.45	1.92	0.18	0.11
VTES		8.39±0.71		8.51±0.60	0.12	0.73	<0.01
VTFS	47	13.97±0.88	18	14.42±0.91	4.11	0.05	0.06
UBDS	59	5.62±0.74	17	5.87±0.62	2.00	0.16	0.03
UBES		7.70±0.89		8.14±0.36	4.10	0.05	0.05
UBFS		13.32±1.37		14.01±0.92	4.23	0.04	0.05
BBDS	62	5.47±0.61	19	5.78±0.44	5.23	0.02	0.06
BBES		7.45±1.00		8.11±0.62	8.29	0.01	0.09
BBFS		12.92±1.31		13.89±0.97	10.52	<0.01	0.11
FXDS	59	5.36±0.44	20	5.50±0.49	1.46	0.23	0.02
FXES		8.07±0.45		8.11±0.66	0.09	0.76	0.00
FXFS		13.37±0.84		13.56±1.04	0.68	0.41	0.01
AA	43	52.91±3.51	16	56.02±2.76	10.18	<0.01	0.15
				2016			
	N_1	M±SD	N_2	M±SD	F	P	η^2
VTDS	49	5.42±0.56	15	5.47±1.32	4.56	0.04	0.07
VTES		8.78±0.48		8.79±0.88	2.65	0.11	0.04
VTFS		14.18±0.79		14.39±1.63	6.41	0.01	0.09
UBDS	58	5.74±0.64	15	6.60±2.21	2.88	0.09	0.04
UBES		8.03±0.66		8.53±0.39	8.08	0.01	0.10
UBFS		13.76±1.17		14.59±0.81	6.56	0.01	0.08
BBDS	54	5.62±0.57	16	5.75±0.44	1.03	0.31	0.01
BBES		7.75±0.81		7.86±0.55	0.22	0.64	0.00
BBFS		13.36±1.26		13.61±0.83	0.61	0.44	0.01
FXDS	49	5.34±0.76	12	5.63±0.59	1.75	0.19	0.03
FXES		7.89±0.47		8.21±0.49	4.55	0.04	0.07
FXFS		13.18±1.02		13.82±1.01	4.12	0.05	0.06
AA	44	54.17±3.11	14	56.48±2.50	6.07	0.02	0.10

Legend: N_1 – number of FG1×OG, N_2 – number of FG2×OG, M±SD – Mean value ± Standard deviation; One Way ANOVA was used: F – F value, p – p value, η^2 – effect size, (partial) eta squared, VTDS - Vault Difficulty Score, VTES - Vault Execution Score, VTFS - Vault Final Score, UBDS - Uneven Bars Difficulty Score, UBES - Uneven Bars Execution Score, UBFS - Uneven Bars Final Score, BBDS - Balance Beam Difficulty Score, BBES - Balance Beam Execution Score, BBFS - Balance Beam Final Score, FXDS - Floor Difficulty Scores, FXES - Floor Execution Score, FXFS - Floor Final Scores, AA – All-Around Score



Legend: VT- vault, UB – uneven bars, BB – balance beam, FX – floor

Figure 1. Combinations of competed apparatuses at the OG2012 and at the OG2016 by FG2×OG.

Group of FG2×OG had numerically higher values than other competitors at OG2012 and at OG2016. By using ANOVA, it was determined that FG2×OG (compared to FG1×OG from OG2012) had significantly higher values in VTFS, UBES, UBFS, BBDS, BBES and BBFS variables while in other variables significant differences were not determined. Significantly higher scores also have been determined in All-Around competitors FG2×OG, in comparison to All-Around competitors FG1×OG.

At OG2016, FG2×OG had significantly higher values in VTDS, VTFS, UBES, FXES and FXFS (than the FG1×OG from the OG2016) while in other variables differences were not determined. All-Around competitors FG2×OG from the OG2016 also had significantly higher values than All-Around competitors FG1×OG.

DISCUSSION

From the total number of female gymnasts that competed at OG2016, 25 (cca. 26%) of them had an experience of previous OG (OG2012). Analysis of the scores which are obtained by FG2×OG, from the OG2012 to the OG2016, generally determine the following: 1) they decrease difficulty of performed vaults, but increase the quality of performance; 2) they significantly improve the quality of performance (UBES) and significantly increase the final score on uneven bars (UBFS); 3) they significantly decrease the

quality of performance and this results in a significant decrease of final score on the balance beam, compared to the results from the OG2012; 4) they increase numerical values of difficulty and the quality of the performance on the floor, compared to the results achieved in the OG2012.

Determined reductions in some scores (VTDS, BBES, and BBFS) is not proper to attribute only to lower gymnasts competition quality, but also to the changes that have occurred in the CoP 2013-2016 (FIG, 2009) in relation to the CoP 2009-2012 (FIG, 2013). Namely, compared to the CoP 2009-2012, in the CoP 2013-2016 some most frequently performed vaults (often the vaults of the highest Difficulty Values, performed on all levels of the major competitions) went through the reduction of the Difficulty Value (Delaš Kalinski, Atiković, Jelaska, & Milić, 2016).

According to the analyzed CoPs, lower ES on the balance beam can not be associated with some significant changes in the rules on this apparatus. However, based on higher values of the BBDS it is possible to assume that the performance of more complex and difficult elements was not that stabile and correct, what led to lower scores of the BBES at OG2016 in relation to the OG2012.

However, the following question arises: did the increase of most scores at OG2016 enable FG2×OG to qualify for the finals?

Referring to the original results, we notice the following: if compared to the OG2012, 14 of 25 FG2×OG All-Around competitors, at OG2016, remained; 10 of 25 FG2×OG have reduced the number of competed apparatuses; one of 25 FG2×OG have increased the number of competed apparatuses and have became All-Around competitor; one of them competed the same (one) apparatus at both OG. From 14 All-Around FG2×OG at OG2016, nine entered All-Around Finals (Elisabeth Black, Carlotta Ferlito, Vanessa Ferrari, Jessica Brizeida Lopez Arocha, Aliya Mustafina, Alexandra Raisman, Elisabeth Seitz, Giulia Steingruber and Teramoto Asuka) and seven entered the apparatus final competitions (vault finals: Giulia Steingruber; uneven bars finals: Aliya Mustafina, Elizabeth Seitz, Jessica Brizeida Lopez Arocha, Gabrielle Douglas, floor finals: Alexandra Raisman, Vanessa Ferrari, Giulia Steingruber).

Four FG2×OG out of eleven, who have competed only one apparatus at OG2016, entered the final competitions (Catalina Ponor on the balance beam, Maria Paseka and Oksana Chousovitina on the vault, and Erica Fasana on the floor).

Based on the aforementioned results of FG2×OG, the quality of all FG2×OG at OG2016 is unquestionable. The assumption is that those consecutive participants used the period of time between the two OG to stabilize and upgrade previously acquired skills. Longer period of complex motor skills learning (primarily skills of elite artistic gymnastics) is needed if we want to acquire the highest stage of motor skills (Schmidt, & Wrisberg, 2008).

At both OG FG2×OG, compared to FG1×OG, had numerically higher values of all scores but significant differences between FG2×OG and FG1×OG have been found only in 50% of the variables (in VTFS, UBES, UBFS, BBDS, BBES and BBFS variables at OG2012, and in VTDS, VTFS, UBES, UBFS, FXES and FXFS variables at OG2016; Table 2). Besides the quality difference among these two groups of competitors, we also assume the impact of age, i.e., longer sports carrier and longer period of deliberate practice.

At OG2012, compared to FG1×OG, FG2×OG had numerically higher values of VTDS and VTES, and significantly higher values of VTFS. Furthermore, at OG2016, compared to FG1×OG, FG2×OG had numerically higher values of VTES and significantly higher values of VTDS and VTFS. Referring to the original results it has been revealed that 5 FG2×OG (of the

total number of 18 Vault Qualifiers) participated at the Vault Qualifications at OG2012, out of which four FG2×OG competed Vault Finals at OG2012 (Maria Paseka, Oksana Chusovitina, Brittany Rogers, and Elsabeth Black). At OG2016, five of 19 Vault Qualifiers were FG2×OG, out of which even three FG2×OG competed in Vault Finals at OG2016 (Maria Paseka, Giulia Steingruber and Oksana Chusovitina). Taking into account the facts of having analysed scores from C-I competition, and the scores of the 1st vault of Vault Qualifiers count for Team Result and Individual All-Around Result (FIG, 2009, 2013), it is not surprising that for the 1st vault Vault Qualifiers chose vaults with numerically higher *DVs* (and sometimes significantly higher) from those performed by All-Around Competitors (Delaš Kalinski, Atiković, Jelaska, & Milić, 2016). Whereas the FG2×OG at both OG formed 1/4th of the group of Vault Qualifiers, and that five (OG2012) or three (OG2016) competed in Vault Finals, their higher scores on vault, compared to FG1×OG, were only logically-achieved results.

Higher values of VTFS of FG2×OG, despite the reduction of the Difficulty Values of the most frequently performed vaults (CoP, 2013), confirm their progression in the quality and complexity of the performed vaults and support a conclusion that female gymnasts can have prolonged development of skills after the age of 20 (Zurc, 2017).

Significantly higher values for FG2×OG in the UBES variable, at OG2012 and at OG2016, confirmed the results of the previous studies. Namely, Ferreirinha et al. (2011) determined that the uneven bars are apparatus which needs more time to train in order to achieve higher technical and aesthetic level of performance. Since for the FG2×OG higher average values of age have been determined at both OGs (at OG2012 FG2×OG was 21.04 old and FG1xOG was 20.23 old; at OG2016 FG2×OG was 25.07 old and FG1xOG was 19.45 old), and probably a longer sports carrier than other female Olympic Games gymnasts, the obtained result can be justified. However, due to the lack of information on the training process of the previously mentioned female gymnasts, and the fact that training workloads as well as sequencing of training sessions are highly variable among individuals/gymnasts (Malina et al, 2013), the influence of longer sports carrier and longer time of deliberate practice on superior levels of performance of uneven bars by FG2×OG remains unknown.

At OG2012, all scores achieved on the balance beam by FG2×OG were significantly higher from the scores achieved by FG1×OG at the same apparatus. Accordingly, it is possible to assert that on this apparatus, FG2×OG group significantly differs from other gymnasts in their technical and aesthetical quality of performance. During the original data introspection, it was found that FG2×OG group included 3 gymnasts (Alexandra Raisman, Catalina Ponor and Gabrielle Douglas) who entered balance beam finals at OG2012. From other 19 FG2×OG who at OG2012 competed on the balance beam in the qualification competition, 11 of them were ranked among first 31 places and the remaining 8 among 57 places. In accordance with those results, the balance beam competing quality can be clearly visible and the obtained results are logical. At OG2016, despite the certain numerical dominance of FG2xOG in all balance beam variables (compared to FG1xOG), significant differences have not been determined.

At both analysed OG, FG2xOG had numerically higher values of all floor variables, than FG1xOG, but the significant difference has been determined only at OG2016 in FXES and (probably) consequently in the FXFS. The reason for significantly higher quality of FG2xOG, compared to FG1xOG, probably stems from the fact that even 4 competitors from

the group FG2xOG, at OG2016, competed in floor finals (Alexandra Raisman, Vanessa Ferrari, Erika Fasana and Giulia Steingruber), and that a member of the FG2xOG group at OG2016 also was Aliya Mustafina, who won the third place in floor finals at OG2012. The difference between FG2xOG and other gymnasts in FXES, support the conclusion how the chronologically older gymnasts have potentially higher forms of capital, compared to a chronologically younger gymnast, is their ability to express themselves artistically (Kerr et al., 2015). The importance of artistry in women's artistic gymnastics has been a concern of the International Gymnastics Federation and was incorporated in its execution score since 2009.

Nine out of 14 FG2xOG All-Around competitors at OG2016 competed in All-Around Finals, six competed in one Apparatus Finals while four competed in two Apparatus Finals. Apart from the fact that participation in any final competition at OG is a major proof of gymnasts quality, due to the fact that nine FG2xOG competitors who competed in All-Around Finals (from OG2012 and from OG2016) make 37% of overall competitors of All-Around Finals, the significant difference between FG2xOG and FG1xOG in AA variable, at both OG, is rather logical.

CONCLUSION

The results of this study determined that the number of FG2×OG (from OG2012 to OG2016) was 25 (almost ¼ of all competitors) which, according to the authors, should not be considered low. At Olympic Games from OG2012 to OG2016, FG2×OG numerically increased most of their scores, placed high at most final competitions, and confirmed the possibility of continuous quality of skills development in mid 20s.

Higher values of FG2×OG in relation to FG1×OG, at both analyzed Olympic Games, suggest that FG2×OG competitive compositions generally have been above-average with regards to the difficulty values. Apart from the mentioned, they have been performed more correctly in the technical and aesthetical sense. Accordingly, such exercising is definitely one of the key factors responsible for their repeated participation at the Olympic Games.

Pursuant to the obtained results, several conclusions can be made and they are as follows: 1) FG2×OG are probably a subject of adequately planned programs that enable their technical and execution evolution; 2) continuous progress of FG2×OG group could be interpreted as resulting from will power, high working capacity and love for hard work which continuously keeps and encourages them to continue to improve their performances; 3) (presumably) higher chronological age of female gymnasts (since FG2×OG are at least 20-year-old), which is characterized by the stability of the motor programs, probably plays a role in competing of FG2×OG.

However, a factor which can be considered as the most important in reaching, retaining and improving that quality, from one Olympic Games to another (individual characteristics of gymnasts, early experiences, preferences, opportunities, habits, training or practice), remains to be determined in other studies.

"The pathway from genes to talent to greatness is often very nuanced and complex" (Kaufman, 2013)

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CORRELATES OF ARTISTRY PERFORMANCE SCORES IN PREADOLESCENT RHYTHMIC GYMNASTS

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Original article

Abstract

This study examined the association between physical abilities, anthropometric characteristics and artistry performance scores in Greek, national level, competitive rhythmic gymnasts. Forty-six preadolescent gymnasts (aged 9.9±1.3 years) underwent a series of physical fitness (balance, flexibility, muscular power and endurance, sport-specific high intensity shuttle run performance) and anthropometric measurements (body composition, and somatotype). Artistry performance score and its sub-components (unity, music and movement, and expression scores) were obtained during a compulsory routine without apparatus. Multiple regression analyses revealed that sideways leg extension and high intensity shuttle run performance accounted for 43.7% ($p < 0.01$) of the variance in the score of artistry. The same fitness parameters accounted for 47.1% ($p < 0.01$) and 53.2% ($p < 0.01$) of the variance in the scores of artistry's sub-components, unity and music and movement, respectively. Muscular endurance of the back extensors and subscapular skinfold accounted for 29.2% ($p < 0.01$) of the variance in the expression score. Ectomorpy was the dominant somatotype component (2.7-3.0-4.2, for endomorphy, mesomorphy and ectomorphy, respectively). The results of this study highlight the importance of hip flexibility, high intensity shuttle run performance, muscular endurance of the back extensors, and specific anthropometric traits as contributing components to the artistry score in young rhythmic gymnasts.

Keywords: *expression, physical abilities, range of motion, somatotype, high intensity shuttle run*

INTRODUCTION

In rhythmic gymnastics competition, the final score attained is the sum of the sub-scores of the difficulty elements, execution and artistry evaluated by judges with specific criteria -deductions- according to the gymnasts' faults, as described in the Rhythmic Gymnastics Code of Points. Currently, the rhythmic gymnastics Code of Points (2012-2016) focuses on artistry, aiming to reshape a competitive routine into an artistry performance. Therefore, the composition of an exercise is based on the movement "vocabulary" of the gymnast, as well as the choreography of those movements over space and time following a selected music.

Artistry performance score is quantified into a total score by adding the scores of its sub-components of unity of composition, relation of movements with music, use of space, and expression (Rhythmic Gymnastics Code of Points, 2012-2016).

At all ages and performance levels, gymnasts undertake age-specific strength and conditioning programs which form the foundation of skills acquisition (Piazza et al., 2014) and optimize training adaptations (Faigenbaum et al., 2009). The association between rhythmic gymnastics competitive performance and physical abilities has been examined in several previous studies (Bobo Arce & Méndez Rial, 2013; Di Cagno et al., 2009; Hume, Hopkins, Robinson, Robinson, & Hollings, 1993; Rutkauskaite & Skarbalius, 2009; 2011). Flexibility, explosive strength, muscular endurance and aerobic capacity have been identified as determinants of competitive performance (Di Cagno et al., 2009; Douda, Toubekis, Avloniti, & Tokmakidis, 2008; Rutkauskaite & Skarbalius, 2011). Furthermore, anthropometric characteristics such as low body fat, long and thin limbs and an ectomorphic somatotype have been pointed out as important selection and performance criteria, distinguishing elite from non-elite rhythmic gymnasts (Ávila-Carvalho, Klentrou, Luz-Palomero, & Lebre, 2012; Di Cagno, et al., 2008; Douda, Avloniti, Kasabalis, & Tokmakidis, 2007; Klentrou & Plyley, 2003; Purenovic-Ivanovic & Popovic, 2014).

A main aim of any training plan is to improve physical fitness components that determine competitive performance. However, an issue of concern is to what extend physical fitness contributes to performance, to precisely define performance components and the physical abilities that are related to each one of them. Emphasis on artistry is a new direction in the evaluation of rhythmic gymnasts. This direction may reduce the excessive training load placed on gymnasts at an early age, and limit the rapid evolution of the body and apparatus difficulty in the competitive routines (Donti, Donti, & Theodorakou, 2014). High training volume results in repetitive loading on gymnasts' musculoskeletal system often in the absence of sufficient recovery time (Karpenko et al., 2003). However, **d**espite artistry being considered as a current demand for success, there is no published information on the association between physical abilities and anthropometric parameters with artistry, probably due to the absence, until now, of well-defined criteria of artistry and to the fact that artistry was traditionally considered a matter of personal style (Angioi, Metsios, Twitchett, Koutedakis, & Wyon, 2009). Rhythmic gymnasts train and compete at international level from a very young age (Karpenko et al., 2003) and thus a high level of artistry is built up based on specific fitness demands, which, so far, remain undetermined. Therefore, the aim of this study was to examine the association between selected physical abilities and anthropometric characteristics with artistry performance score in national level, competitive, preadolescent, rhythmic gymnasts.

METHODS

Forty-six national level competitive preadolescent rhythmic gymnasts, aged 9.9±1.3 years, participated in this study. A summary of the gymnasts' characteristics is presented in Table 1. Gymnasts were training on a daily basis for approximately 24 hours per week and participated in competitions 3-4 times a year. As a condition of participation in the study all gymnasts should have ranked up to the 50th place in the national championships of their age category, as it was thought that artistry is more accurately evaluated in well-trained gymnasts. Written parental consent was provided for all gymnasts after full verbal and written explanation of

the data collection procedures. The study was approved by the University's Institutional Review Board and all procedures were in accordance with the Code of Ethics of the World Medical Association (Helsinki declaration of 1964, as revised in 2013).

The current study required the participants to complete 3 testing sessions at their training facilities, performed 5-7 days apart, within-2-3 weeks following the national championships. The first testing session included anthropometry (stature, body mass, 4 skinfolds thickness, 2 bone-breaths, 2 limp-girths, and arm length) and familiarization with the physical abilities tests. During the second testing session one International Gymnastics Federation (F.I.G) judge (with 30 years of judging experience and serving as a Reference Judge in official competitions), evaluated gymnasts' artistry in a compulsory routine without apparatus. A compulsory routine without apparatus is a pre-requisite for qualification by the National Gymnastics Federation. This routine includes specific body elements and is performed following a selected music, common for all the gymnasts of each age category. Furthermore, a routine without apparatus where only body movements are evaluated is indicating aesthetic proficiency of the gymnast and consists the 'basis' of further development. The routine was evaluated by the following criteria according to the Rhythmic Gymnastics Code of Points (2012-16): the unity of composition, the relation of music and movement and the gymnasts' expression. Because the compulsory routine had a predetermined use of space there was no deduction for this criterion. Errors or failures according to the above criteria resulted in deductions. In the third testing session, gymnasts underwent a series of physical abilities tests (balance, flexibility, muscular power and endurance, and high intensity shuttle run performance).

Body mass and standing height were measured with a calibrated digital scale and a stadiometer (Seca 710, and Seca 208, Hamburg, Germany). Body composition was estimated by measuring the skinfold thickness on two sites of the body (subscapular and triceps) using a Harpenden skinfold caliper (British Indicator, UK), and the equation of Slaughter et al. (1988) for girls aged less than 18 years. Somatotype was determined according to the methodology of Carter (2002) using the following anthropometric variables: stature, body mass, 4 skinfolds (triceps, subscapular, supraspinal, medial calf), 2 bone breadths (biepicondylar humerus and femur) and 2 limb girths (arm flexed and calf). All measurements were taken on the right side of the gymnasts. The mean value of two consecutive measurements was registered for further analysis. A single researcher, experienced in kinanthropometry, performed all measures in accordance with the International Society for Advancement of Kinanthropometry, guidelines.

Static balance was assessed by a rhythmic gymnastics specific test (Kioumourtzoglou, Derri, Mertzanidou, & Tzetzis, 1997). Gymnasts remained on the ball of their foot with their arms held above their head and the free foot at a low "passé" for as long as possible. Performance was recorded in seconds. Athletes completed 3 trials and the best was used for further analysis. Thirty seconds of rest were provided between trials. The intra-class correlation coefficient (ICC) for the balance test was 0.85 (p<0.01).

Shoulder flexion was measured according to the procedures described by Sleeper, Kenyon, and Casey (2012). From a prone position, with the shoulders flexed at 180°, gymnasts gripped a wooden stick and raised both arms. Shoulder flexion was determined by dividing the height attained by the stick with the length of the athlete's arm and then taking the arcsine of this ratio. Arm length was measured from the tip of the acromion to the tip of the metacarpal bone of the middle finger.

Shoulder extension was measured using the same procedure, with the gymnasts lying in a prone position and lifting their arms behind their back. The ICCs for shoulder flexion and extension tests were 0.94 (p<0.01) and 0.97 (p<0.01), respectively.

The sit and reach test (American College of Sports Medicine, 1998) was used to assess hamstrings and lower back flexibility. The ICC for the sit and reach test was 0.92 (p<0.01). To assess the functional excursion of the hamstrings, straight leg raise range of motion (ROM) as described by Heyward (2005) was used. Markers were placed on the hip, knee and ankle joints of the preferred leg and ROM was calculated as the angle between the lifted leg and the horizontal using a digital camera (Casio Exilim Pro EX-F1) at 30 frames per second and Kinovea Video Analysis Software (v 0.8.15). The sideways leg extension was used to assess specific hip flexibility related skills, which included hip flexion, abduction and external rotation (Angioi, et al., 2009). Assessment of passive range of motion of the hip required the gymnast to move the joint using her hand to its range of motion limit. The angle between the two legs was measured using Kinovea software, as described above. The ICCs for the straight leg raise and sideways leg extension were 0.91 (p<0.01) and 0.96 (p<0.01).

The "bridge" test - the distance from the outer part of the wrist to the outer part of the heel- assessed body hyperextension (Rutkauskaite & Skarbalious, 2011). Since the height of the gymnast may affect the distance between wrists and heels the measurement was standardized by subtracting the distance between wrists and heels from the gymnast's height with the arms raised (up to the wrist) and then dividing it by the height with the arms raised. The ICC for the body hyperextension test was 0.89 (p<0.01). All flexibility measurements were made twice and the best result was used for further analysis.

For the assessment of muscular endurance three different field tests were used. The first was the one min push-ups test (Ballady, Berra, & Golding, 2000), which is an indicator of the upper body muscular endurance. The gymnasts were instructed to keep the body in a straight position and bend their elbows until the chin touched the mat and then fully extend their arms. The maximum number of push-ups performed consecutively was used for further analysis. The ICC for the 1 min push-ups test was 0.91 (p<0.01). The one min sit-up test was used to measure muscular endurance of the abdominal muscles (Barker et al., 2007). Athletes crossed their arms over their chest with hands on their shoulders at all times. From this position, gymnasts raised their upper torso until their elbows touched their thighs and then lowered their upper torso until their shoulder blades touched the floor. The maximum number of correctly executed repetitions was recorded. The ICC for the one min sit-up test was 0.91 (p<0.01). Muscular endurance of the back extensors was evaluated using a previously published test (Trošt-Bobić & Radaš, 2010). Gymnasts lay face down and performed trunk hyperextensions to 90° (from a position where the chest touched the floor to a position where the shoulder blades touched a fixed object). The maximum number of repetitions performed in 30 seconds was recorded. The examiner assisted by anchoring the gymnasts' feet on the ground. The ICC for the back extension test was 0.91 (p<0.01). Athletes completed 2 trials of each muscular endurance test and the best value was used for further analysis.

Lower limbs' muscular power was assessed by the counter movement jump (CMJ) and the drop jump (DJ) from 30 cm height. Gymnasts executed for each jump two repetitions and the highest value was used for further analysis. For the CMJ, gymnasts were instructed to perform a countermovement until the knees were

bent at approximately 90 degrees, and then immediately jump up as high as possible. For the drop jump, gymnasts jumped down from a 30 cm box onto the mat and then immediately performed a maximal vertical jump. Athletes were instructed to keep their hands on their hips throughout the test and land on the same spot. Jump height was calculated from flight time, using an OptoJump System (Microgate, Bolzano, Italy). The ICCs for CMJ and DJ were 0.96 and 0.95 (p<0.01).

High intensity shuttle run performance was tested with a gymnastics specific test as described by Sleeper, Kenyon and Cassey (2012). Two cones were placed diagonally in the corners of a gymnastics floor area (12m x 12m). Gymnasts performed five consecutive 17 m shuttle sprints (running across the diagonal length of the gymnastics floor). The total time taken to run the five sprints was measured using a digital stopwatch. Athletes completed 2 trials and the best time was used for further analysis. The ICC for this test was 0.91 (p<0.01).

Statistical analyses were carried out using SPSS (IBM SPSS Statistics Version 23). Data are presented as means and standard deviations for all variables. The normality of data distribution was checked with the Kolmogorov-Smirnov test. The Pearson's correlation coefficient (r) was used to detect linear associations among the selected physical abilities, anthropometric characteristics, and the artistry scores. Multiple regression analyses were used to investigate which physical abilities and anthropometric characteristics contributed most significantly to the artistry performance score and to each sub-component of artistry (unity, music and movement and expression scores) separately. The intra-class correlation coefficient (ICC) was used as a measure of test-retest reliability (Hopkins, Marshall, Batterman, & Hanin, 2009) for all the variables examined in this study and was determined by using a 2-way mixed model analysis of variance. Statistical significance was accepted at p<0.05. All analyses were performed using SPSS (version 20.0, SPSS Inc., Chicago, IL, USA).

RESULTS

The artistry score as well as the separate scores of its sub-components, (i.e., unity, music and movement and expression), in deduction points, are presented in Table 1. The results of the anthropometric characteristics assessment tests are presented in Table 1 and physical fitness assessment tests are presented in Table 2. The scores of artistry and its sub-components were significantly correlated with several anthropometric characteristics (Table 1) and physical abilities (Table 2).

Multiple regression analyses revealed that sideways leg extension and high intensity shuttle run performance accounted for 43.7% of the variance in the artistry score (Table 3). The same variables -sideways leg extension and high intensity shuttle run performance- accounted for 47.1% and 53.2% for the sub-scores of unity and music and movement respectively. Muscular endurance of the back extensors and subscapular skinfold accounted for 29.2% for the score of expression (Table 3).

The somatotype distribution of the gymnasts is shown in Figure 3. The dominant somatotype component was ectomorphy (2.7-3.0-4.2 values for endomorphy, mesomorphy, ectomorphy, respectively, Table 1 and Fig. 1).

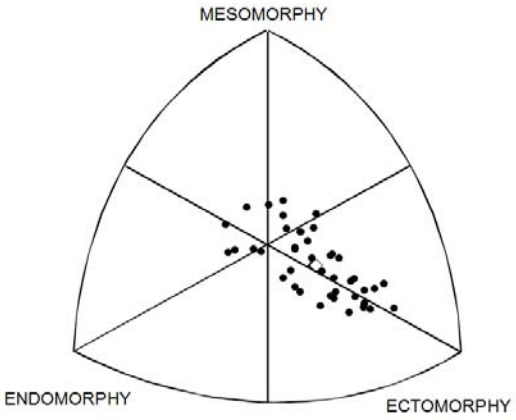

Figure 1. Somatotype distribution of the rhythmic gymnasts. Filled circles are individual data, while open diamond represents the average somatotype of this group of athletes.

Table 1
Correlations between artistry and its sub-components' scores (in deduction points) and participants' anthropometric characteristics.

	Mean±SD	Artistry	Unity	Music & movement	Expression
Artistry score (in deduction points)	0.96±0.26				
Unity score	0.32±0.09	.810**			
Music & movement score	0.33±0.09	.907**	.861**		
Expression score	0.32±0.14	.813**	.343*	.550**	
Participants' characteristics					
Age (years)	9.9±1.3	-.341*	-.245	-.371*	-.250
Training experience (years)	2.4±1.3	-.374*	-.199	-.346*	-.379**
Anthropometric characteristics					
Height (cm)	137.9±7.7	-.376**	-.300*	-.372*	-.267
Weight (kg)	29.2±3.9	-.304*	-.316*	-.338*	-.133
Body fat (%)	15.5±1.7	.357*	.465**	.438**	.130
Body fat (kg)	4.5±0.7	.052	.044	.104	.052
Lean body mass (kg)	24.7±3.4	-.353*	-.365**	-.403**	.160
Arm length (cm)	60.1±3.7	-.253	-.177	-.288	-.165
Supraspinal skinfold (mm)	5.8±1.4	.441**	.356*	.460**	.331*
Subscapular skinfold (mm)	7.2±1.2	466**	.325*	.485**	.407**
Triceps skinfold (mm)	8.7±1.5	.280	.388**	.388**	.055
Medial calf skinfold (mm)	8.5±1.9	.323*	.410**	.367*	.145
Humerus biepicond.breadth (cm)	4.8±0.3	-.242	-.058	-.204	-.277
Femur biepicond. breadth (cm)	7.1±0.4	-.123	-.032	-.084	-.131
Relaxed arm girth (cm)	19.2±1.2	-.312*	-.280	-.347*	-.151
Flexed arm girth (cm)	20.9±1.3	-.387**	-.353*	-.443**	-.194
Calf girth (cm)	27.9±1.8	-.286	-.249	-.336*	-.152
Endomorphy	2.71±0.55	.511**	.455**	.560**	.339*
Mesomorphy	2.99±0.70	.133	.143	.109	.098
Ectomorphy	4.22±0.88	-.277	.-108	-.215	-.323*

*: $p<0.05$ and **: $p<0.01$

Table 2
Correlations between artistry score and its sub-components' scores (in deduction points) and physical fitness parameters.

	Mean±SD	Artistry	Unity	Music & movement	Expression
Physical fitness parameters					
Shoulder flexion (°)	30.4±7.3	-.150	-.302*	-.187	-.034
Shoulder hyperextension(°)	37.5±4.8	-.074	-.108	-.027	-.053
Sit and reach (cm)	16.6±5.1	-.246	-.130	-.202	-.196
Straight leg raise (°)	165.1±13.0	-.477**	-.439**	-.103	-.277
Sideways leg extension (°)	154.6±15.8	-.589**	-.586**	-.566**	-.343*
Spinal flexibility ratio (%)	85.7±7.5	-.070	-.105	-.634**	-.011
Push ups (repetitions)	16±9	-.154	-.218	-.270	-.001
Abdominal muscular endurance (repetitions)	31±8	-.339*	-.251	-.451**	-.216
Back extension endurance (repetitions)	24±4	-.401**	-.240	-.293*	-.436**
CMJ with 2 legs (cm)	21.1±2.4	-.035	-.066	-.011	-.129
Drop jump from 40cm (cm)	22.0±3.1	-.085	-.081	-.157	-.000
High intensity shuttle run performance (s)	19.54±1.50	.465**	.513**	.524**	.225
Balance on the ball of the foot (s)	13.90±13.22	-.349*	-.199	-.364*	-.317*

*: $p<0.05$ and **: $p<0.01$

Table 3
Results of the multiple regression analyses using the physical abilities and anthropometric characteristics as predictors of the scores of artistry, unity, music and movement and expression (in deduction points).

ARTISTRY	Unstandardized coefficient *B*	*SEB*	Standardized beta coefficient	Adjusted R^2
Physical abilities				0.437**
Constant	1.088	.545		
Sideways leg extension	-.008	.002	-.509**	
High intensity shuttle run performance	.061	.020	.348**	
UNITY	Unstandardized coefficient B	*SEB*	Standardized beta coefficient	Adjusted R^2
Physical abilities				0.471**
Constant	.286	.176		
Sideways leg extension	-.003	.001	-.494**	
High intensity shuttle run performance	.023	.007	.400**	
MUSIC AND MOVEMENT	Unstandardized coefficient *B*	*SEB*	Standardized beta coefficient	Adjusted R^2
Physical abilities				0.532**
Constant	.337	.166		
Sideways leg extension	-.003	.001	-.542**	
High intensity shuttle run performance	.023	.006	.400**	

EXPRESSION	Unstandardized coefficient B	*SEB*	Standardized beta coefficient	Adjusted R^2
Physical abilities				0.292**
Constant	.294	.145		
Muscle extensors of the back	-.013	.004	-.399**	
Subscapular skinfold	.043	.015	.366**	

SEB: standard error of B**;** **: $p < 0.01$, *: $p < 0.05$

DISCUSSION

The aim of this study was to examine the association between artistry score, physical abilities and anthropometric characteristics in preadolescent, national level, competitive rhythmic gymnasts. The results demonstrated that hip flexibility (sideways leg extension) and high intensity shuttle run performance, accounted for a large part of the variance of the artistry score as well as to its separate sub-components, unity and music and movement. Results from the regression analysis revealed that muscular endurance of the back extensors and subscapular skinfold significantly contributed to the expression score. Furthermore, this study provides information on values of anthropometric characteristics and physical abilities of preadolescent, competitive rhythmic gymnasts, associated with artistry score, thus helping coaches monitoring training and selection processes.

Sideways leg extension was the variable that demonstrated the higher contribution to the variance of the artistry score and its sub-components unity and music and movement (Table 3). Sideways leg extension includes the combined actions of hip flexion, abduction and external rotation (Angioi et al., 2009) and is suggested as a specific hip flexibility test for dancers (Wyon et al., 2007). Furthermore, it is recently suggested as a lower limb flexibility test in rhythmic gymnastics (Santos, Lemos, Lebre, & Ávila-Carvalho, 2015). Assessment of passive hip flexibility in this test requires the gymnasts to move their limb sideways using their hands into its range of motion limit. The execution of sideways leg extension implies a firm postural control, body alignment and balance in order to properly stand while lifting and holding the leg sideways; hence it is a pre-requisite for turning, leaping and landing. Importantly, this test demonstrated the higher contribution to the variance of the artistry score compared to other commonly used lower limb flexibility tests, such as straight leg raise and sit and reach. However, when designing a testing battery for athletes, and especially for well-trained athletes, it is important that the testing battery provides a valid insight into sport-specific performance (McGuigan, 2014). General tests, do not always correlate well with athletes' competitive performance (McGuigan, 2014). For example, in the present study, sit and reach -which is a valid and reliable test assessing hamstrings and lower back flexibility for physically active individuals- demonstrated no association with artistry and its sub-components (Table 2). This, may be explained by the fact that rhythmic gymnasts at this age, have already acquired a high level of hamstrings and lower back flexibility and sit and reach test is not "sensitive" to detect changes in hip flexibility associated with complex types of movement.

One interesting finding of the present study was that high intensity shuttle run performance explained a significant part of the variance of the scores for artistry, as

well as of the scores for unity and music and movement (Table 3). Performance time during this high intensity shuttle run test depends on sprint speed, speed endurance (Nimphius, 2014) as well as eccentric and concentric power and whole body coordination required for the change of direction (Hader, Palazzi, & Buchheit, 2015). The ability to decelerate, change direction and reaccelerate is an essential component of youth sports, influenced by training age, growth and maturation (Nimphius, 2014). However, despite its importance, this physical ability has not been examined in gymnastics sports. According to the rhythmic gymnastics Code of Points (2012-2016), unity refers to developing a unified image with transitions from one movement to another, including contrasts in the speed, direction and intensity, without stops and/or hesitation. Music and movement is defined as the gymnasts' ability to express the character of the music in accordance with tempo and rhythm, through continuous bodywork. Both criteria imply the physical attribute of changing of direction speed while fine-tuning body positioning, throughout a gymnastics routine. Furthermore, the duration of the high intensity shuttle run performance test in the present study was ~20 s and this time may represent the total high intensity part of the 75-90 s routine during competition. The association between high intensity shuttle run performance with artistry scores warrants further investigation, as the present study revealed its important contribution to the artistry score.

The fact that muscular endurance of the back extensors and subscapular skinfold accounted for a 29.2% of expression may be explained by the description of this criterion (Table 3). Gymnasts should create "shapes" in space through participation of all body segments (head, shoulders, trunk, arms, legs) in order to express the idea of the choreography. Therefore, the endurance of the back extensors is important in order to hyperextend the trunk in balances, leaps and acrobatic elements, and regain a firm standing position throughout a competitive routine. The contribution of the subscapular skinfold to the variance of the expression score may possibly be due to the fact that in a lean body, movements are better defined. However, a large proportion of the variance in expression score remains unaccounted for by the physical abilities and anthropometric characteristics measured in the present study. It is plausible that expression, as an act of communicating emotions through movement, is also related to different skills and personality traits and/or is developed at a later age. Furthermore, although the music theme in the routine was common for all the gymnasts that participated in this study, a different music accompaniment may have led to different movement accuracy, expression and interpretation, as also suggested by recent research (Ahmed, 2016; Gantcheva, 2016).

Several authors have pointed out anthropometric characteristics as contributing factors to rhythmic gymnastics performance (Ávila-Carvalho, Klentrou, Luz-Palomero, & Lebre, 2012; Di Cagno, et al., 2008; Douda, Toubekis, Avloniti, & Tokmakidis, 2008). Nevertheless, the preadolescent, gymnasts of this study demonstrated a balanced ectomorph somatotype, thus confirming previous evidence on the importance of ectomorphy as a selection criterion (Purenovic-Ivanovic & Popovic, 2014; Vernetta, Fernández, López-Bedoya, Gómez-Landero, & Oña, 2011) (Figure 1). A balanced ectomorph somatotype implies that the ectomorphic component is the dominant one and the remaining two (endomorphy, mesomorphy) have equal prevalence and moderate values (Purenovic-Ivanovic & Popovic, 2014). In the present study it was also found a positive correlation of endomorphy with the artistry score -in deductions- (Table 1). This finding, in addition to the significant

correlations between subscapular and supraspinal skinfolds and lean body mass with the deductions of artistry score (Table 1), indicate that a lean body shape may be indirectly encouraged by the Gymnastics Federation Code of Points, as previously suggested by other authors (Ávila-Carvalho, Klentrou, Luz-Palomero, & Lebre, 2012; Kosmidou et al., 2015).

An interesting finding of the present study was that age and training experience significantly correlated with artistry score in young gymnasts (Table 1). One year of training experience may not be very important for a child training 2 days a week, for 1 hour each time, however, in rhythmic gymnastics, young gymnasts train for 6 days a week, for 4 hours each time, therefore, a year of training and competing experience may significantly enhance their performance.

CONCLUSIONS

The initial years of practice are crucial for further success in sports. This study, examined the association between physical abilities, anthropometric parameters and Artistry performance as evaluated with the criteria given by the Rhythmic Gymnastics Code of Points. However, other factors such as, gymnast's personality traits, and social and cognitive skills may also contribute to artistry performance. In conclusion, the results of this study highlight the importance of sport-specific flexibility, high intensity shuttle run performance, muscular endurance of the back extensors, and specific anthropometric traits, as contributing components to the artistry score of competitive, preadolescent rhythmic gymnasts. In addition, this study provides reference values for gymnasts' physical capacities and anthropometric characteristics. These results, using a sample of competitive, preadolescent rhythmic gymnasts, may enable implementing more effective training programs aiming to enhance artistry score. Further research is warranted on the association of artistry with fitness variables at older developmental ages thus, profiling the needs of the sport, and helping coaches to prioritize certain training focus, which is imperative for young athletes.

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DANCE STEPS, DYNAMIC ELEMENTS WITH ROTATION AND THROW AND MASTERY ELEMENTS IN RHYTHMIC GYMNASTICS ROUTINES

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Original article

Abstract

Analyze of individual elite routines allows to gain more knowledge about the performance of the RG structure. Therefore, the aim of this study is to know the difficulty elements diversity (dance steps, masteries and dynamic elements with rotation and throw) in individual routines of elite gymnasts who competed at the 2013 and 2014 Lisbon RG World Cup and to compare these characteristics across different ranking groups. 288 official difficulty forms of 4 routines were analyzed. The gymnasts' routines were clustered into three groups according to their ranking position. Non-parametric Kruskal-Wallis and Mann-Whitney tests were used. Pearson Correlation was used to analyze the association degree of the difficulty elements in the gymnasts' final score. The best gymnasts presented routines with some different characteristics, however, we verified a high similarity in the difficulties elements analyzed in the compositions that can compromise the originality and variety of this sport. We observed that the higher gymnasts' final score, have also higher departure difficulty score; lower number of combinations of base and criteria in masteries; higher number of non-fundamental and lower number of fundamental group elements in masteries. On the other hand, higher number of masteries and number of additional criteria of body rotations in dynamic elements with rotation and throw, lower the gymnasts' final score. However, we believe that the real differences in the ranking groups is mostly justified by evaluation of the judges of the difficulty elements presented in the official Difficulty forms and in the execution quality of the gymnasts.

Keywords: *difficulty elements, individual routines, elite gymnasts, rhythmic gymnastics.*

INTRODUCTION

Rhythmic Gymnastics (RG) is characterized by a high level of technical demand in the difficulty elements and apparatus techniques of rope, ball, hoop, clubs and ribbon, combined with the aesthetic and artistic aspects (Breitkreutz & Hökelmann, 2012; Hökelmann et al., 2012) RG competition routines are assessed according to the international RG Code of Points (RG-CoP). Every 4 years, at the end of the Olympic cycle, this code is improved and published by the RG Technical Committee of the International Gymnastics Federation (FIG) (Ávila-Carvalho et al., 2010). The main purpose is to provide a more objective evaluation of the competition routines and promote the sport development (Ávila-Carvalho et al.,

2012). The RG-CoP changes increase the difficulty and the demand of the competition routines requirements (Lisitskaya, 1995; Oliveira et al., 2004), according to the actual practice of the sport. However, the Code also determines the direction in which RG will evolve (Trifunov & Slobodanka, 2013).

The knowledge of the content of the high level gymnasts' competition routines including the details concerning the specificity of their components, can contribute to characterize the requirements allowing improvements in a gymnasts' preparation for competitions (Ferreirinha et al., 2011). Therefore, to identify trends in the performance structure, to understand how the RG-CoP is interpreted and to meet the compositional strategies used by reference coaches (Ávila-Carvalho et al., 2012) can be also useful information to coaches and gymnasts as feedback to determine the training models in order to improve performance (Fernandez-Villarino et al., 2013). However, the small number of studies about competition routines in RG (Agopyan, 2014) can be justified by the constant evolution of RG-CoP requirements. Thus, according to Lebre (1993), it becomes difficult to compare the results.

The content of the competition routines is represented by music, composition design and chose/combination of body and apparatus elements (Hökelmann et al., 2013), therefore, it is influenced by several qualitative and quantitative factors. The qualitative factors are highly dependent on subjective perceptions and in the other hand, the quantitative factors are more objective and, therefore, more suitable for performance analysis (Breitkreutz & Hökelmann, 2012; Hökelmann & Blaser, 2006; Hökelmann et al., 2012). The quantitative factors in individual routines in the 2013-2016 Olympic cycle include the difficulty elements: body difficulties; dance steps; masteries; dynamic elements with rotation and throw (DER) (FIG, 2012).

The aim of this study are to analyze the difficulty elements diversity and variety (dance steps, masteries and DER) of the individual routines of elite gymnasts who competed at the 2013 and 2014 Lisbon RG World Cup and to compare these characteristics across different ranking groups. Furthermore, to identify the difficulty elements included in the routines that contribute the most to the success in competition. The hypothesis of the study is that the finalists gymnasts (top 8 ranking gymnasts) have routines with higher scores and more complex elements (in quantity and difficulty) than the other lower-ranked gymnasts.

METHODS

A total of 288 individual routines from different countries performed in 2013 and 2014 Lisbon RG World Cups (Portugal) were analyzed according to 2013-2016 RG-CoP rules (FIG, 2012). This study was approved by the World Cup Organization.

Each participant performed 4 routines (hoop, ball, clubs and ribbon) and the analysis was carried out based on the Difficulty forms submitted prior to the competition by the coaches and not evaluated by the judges.

The gymnasts were clustered into three groups according to their ranking routine in each apparatus: 1st Group (Finalists) – 1st to 8th place in the ranking; 2nd Group – 9th to 22nd place in the ranking; 3rd Group – 23rd to 36th place in the ranking.

The analysis was conducted by two international RG judges. The high intraclass correlation coefficient values in the relative reliability analysis: intra-examiner (0.98) and inter-examiner (0.97), demonstrated high objectivity in the evaluations.

Table 1
Summary of fundamental and non-fundamental apparatus group elements of the RG-CoP (2013-2016).

Apparatus	Fundamental apparatus group elements	Non-Fundamental apparatus group elements
Hoop 	Passing through the Hoop with the whole or part of the body	Passing over the Hoop with the whole or part of the body
	Roll of the Hoop over minimum 2 body segments	Small throw and catch
	Roll of the Hoop on the floor	Throws or catches: Medium or Large throw
	Rotations of the Hoop around its axis: One free rotation between the fingers or on the part of the body / Series of rotations on the floor	Apparatus handling: Figure 8 with ample body movement; Large circles; Transmission of the apparatus around any part of the body or under the leg(s)
	Series of rotations around the hand / One free rotation around a part of the body	Unstable balance on the part of the body
Ball 	Roll of the Ball on the floor: Large (min. 1 meter) or series of small rolls	"Flip-over" movement of the Ball; Rotations of the hand(s) around the Ball; Series of assisted small roll; Roll of the body over the Ball on the floor; "Trust"/push of the Ball from different parts of the body
	Roll of the Ball over minimum 2 large body segments	Throws or catches: Medium or Large throw
	Catch of the Ball with one hand	Small throw and catch
	Series of small bounces or one high bounce; Visible rebound from a part of the body	Apparatus handling: Large circles; Transmission of the apparatus around any part of the body or under the leg(s)
	Figures eight of the ball with circle movements of the arms and ample movement of the trunk	Unstable balance on the part of the body
Clubs 	Mills: at least 4 small circles of the Clubs with time delay and by alternating crossed and uncrossed wrists/ hands each time	For 1 or 2 clubs: Free rotations on the part of the body or on the floor; Rolls on the part of the body or on the floor; Rebound from the body; "Sliding"; Tapping (min 1); "Trust"/push of the Club from different parts of the body
	Asymmetric movements of 2 Clubs	Small throw and catch of 1 Club
	Small throws and catches with rotation of 2 Clubs together simultaneously or alternating	Throws or catches: Medium or Large throw
		Throws or catches of 2 Clubs, simultaneous or asymmetric
		"Cascade" throws (double or triple)
		Apparatus handling: Figure 8 with ample body movement; Large circles; Transmission of the apparatus around any part of the body or under the leg(s)
		Unstable balance on the part of the body
Ribbon 	Spirals (4-5 waves); Spirals on the floor	"Boomerang" (in the air or on the floor)
	Snakes (4-5 waves); Snakes on the floor	Rotational movement of the stick around the hand; Roll of the stick on the part of the body; Rebound of the stick from the part of the body; Wrapping; Movement of the Ribbon around a part of the body created when the stick is held by different parts of the body
	Passing through or over the pattern of the Ribbon	Small throw and catch
	"Echappé"	Throws or catches: Medium or Large throw
		Apparatus handling: Figure 8 with ample body movement; Large circles; Transmission of the apparatus around any part of the body or under the leg(s)
		Unstable balance on the part of the body

Table 2
Summary Table of Additional Criteria of throw, body rotation and catch of apparatus in DER.

Additional criteria - throw of apparatus in DER
Outside of visual control during the throw
Without the help of the hands during the throw
Passing through the apparatus during throw
Throw with rotations around its diameter; on horizontal or vertical plane
Throw with oblique plane
Throw of 2 Clubs
Asymmetric throw of 2 Clubs
Throw under the leg/legs
Throw after bounces on the floor, after rolling on the floor, etc.
Additional criteria - body rotation in DER
Change of body rotation axis under the throw or during the catch of the apparatus
Change of level (two levels: flight/standing and floor)
Additional criteria - catch of apparatus in DER
Outside of visual control during the catch
Without the help of the hands during the catch
Passing through the apparatus during catch
Mixed catch of Clubs
Catch under the leg/legs
Direct catch in a roll
Direct re-throw / re-bound
Direct catch in rotation
Catch of the Ball with one hand

For statistical analyses of the data we used the Statistical Package for Social Sciences – version 20.0. The level of significance was set at $\alpha = 0.05$. Descriptive statistics were calculated using the mean, standard deviation (SD) and range values. The Kruskal-Wallis and Mann-Whitney non-parametric tests were used to compare the ranking groups. Pearson Correlation was performed to analyze the association degree of the difficulty elements in the gymnasts' final score.

RG-CoP rules (FIG, 2012):

- Fundamental (FGE) and non-fundamental apparatus group elements (NFGE): Table 1 presents the FGE and NFGE in hoop, ball, clubs and ribbon routines. These apparatus elements are performed in the dance steps, masteries and body difficulties, and they should be included in the official Difficulty forms.

- Masteries: The mastery consists of, at least, 1 base (1B) – FGE and/or NFGE, plus a minimum 2 criteria (2C). Or 2 bases (2B) plus minimum 1 criteria (1C).

- DER: Table 2 shows the additional criteria of throw, body rotation (during the fly of the apparatus) and catch of the apparatus performed in the DER.

RESULTS

Dance steps

The gymnasts presented similar number of dance steps and FGE in dance steps (Figure 1). No significant differences were found in the groups in all dance steps variables evaluated: number of dance steps (p=0.981); number of FGE per dance steps (p=0.728); number of dance steps by apparatus: hoop (p= 0.259); ball (p=0.685); clubs (p=0.357) and ribbon (p=0.694); number of FGE by apparatus: hoop (p= 0.899); ball (p=0.208); clubs (p=0.683) and ribbon (p=0.477) routines.

In Figure 1, we can see that all groups showed a higher number of dance steps in ribbon routines and higher number of FGE in dance steps in the clubs routines.

Masteries (M)

The routines presented 6 different combinations (Figure 2) of bases and criteria.

Although not necessary, many routines presented more criteria and/or bases than the required by the RG-CoP (FIG, 2012), because the element is valid if the gymnasts perform without execution faults at least the minimum number of base and criteria elements. The most routines presented the combination 1 base plus 2 criteria (3.62±2.11 masteries), probably because this is the easiest combination of bases and criteria required by the RG-CoP (FIG, 2012).

We verified that the higher the ranking position, the fewer types of combinations were observed: finalists (4); 2nd Group (5) and 3rd Group (6).

The gymnasts of 3rd Group showed a high range in the number of masteries (Table 3). Furthermore, this ranking routines presented a higher of masteries elements than the remaining groups, although no significant differences were found in the number of masteries in all groups analyzed (p=0.654). On the other hand, we observed a lower range in the number of masteries in finalists' routines.

The choice between using FGE or NFGE in masteries showed different values for the different groups (Table 3), although significant differences were found only in routines of 3rd Group (p=0.006). This group have a significant superior use of FGE in masteries. We observed that the higher the ranking position, higher the number of NFGE and lower the number of FGE in these elements in the routines.

Significant differences also were verified in finalists versus 3rd Group (p=0.013) in the number of masteries with NFGE.

The routines were analyzed by apparatus (Table 3) and we did not observe significant differences between groups in number of masteries: hoop (p= 0.369); ball (p=0.338); clubs (p=0.831) and ribbon (p=0.476). However, the ball and hoop routines in all groups analyzed had a higher number of masteries.

When we analyze the minimum and maximum values in Table 3, we observed that all apparatus routines of 3rd Group and finalists presented respectively, the higher and the lower range in the number of masteries.

The FGE in masteries are more used in hoop and ball routines, and NFGE are more used in clubs and ribbon routines in all groups analyzed. Significant differences were found in the number of masteries with FGE only in clubs routines (p=0.005), in finalists and 2nd Group versus 3rd Group, and in the number of masteries with NFGE in hoop routines (p=0.004) in finalists versus 3rd Group.

The masteries can be performed in body difficulty elements and we observed in Figure 3 that 39.1% of finalists, 40.2% of 2nd Group and 36.6% of 3rd Group routines presented at least one mastery performed during a body difficulty (jumps/leaps, balances or rotations). However, the 3rd Group showed higher number of masteries per routine, although without statistical significance.

When we compared the use of masteries performed during different body groups elements, no significant differences were found: rotations (p=0.833); balances (p=0.953) and jumps/leaps (p=1.000). However, the finalists have higher number of masteries performed during rotations and lower number performed during jumps/leaps than the other groups (Figure 3). Furthermore, balances are the body difficulty most performed during masteries in all groups analyzed.

Dynamic elements with Rotation and throw (DER)

According to the analysis of the official Difficulty forms, we observe that all routines had 3 DER elements. Furthermore, no significant differences were found in the ranking groups in all variables of DER. The 1st, 2nd and 3rd DER presented similar values in each of the criteria analyzed (Figure 4): number of rotations (p=0.337); total additional criteria (p=0.806); criteria of throw (p=0.862); criteria of body rotation (p=0.139) and criteria of catch (p=0.262).

The routines showed in average, for each DER element 3.3±0.4 rotations and 3.6±1.0 additional criteria: 0.9±0.6 criteria during the throw, 1.7±0.6 criteria of body rotation during the fly of apparatus and 1.0±0.7 criteria during catch.

The DER variables were analyzed per apparatus and no significant differences were found between the ranking groups in all apparatus (Table 4). However, we can highlight some results observed. The ribbon routines have the higher number of rotations and additional criteria of body rotation in all groups analyzed, however, these routines have a low number of additional criteria performed mainly during throw and catch of the apparatus.

The additional criteria are more used in hoop and clubs routines than in ball and ribbon routines. Among these additional criteria, we verified higher number of body rotations criteria during the fly of the apparatus in all apparatus and groups, except in finalists hoop routines.

The hoop routines showed a high and similar number of the three additional criteria performed in the DER (during the throw, fly and catch of the apparatus). In ball routines, we observed a low number of additional criteria performed only during the throw of the apparatus. In these routines, the DER have a higher number of criteria during the fly and catch of the apparatus. In the clubs routines, we can see a low number of additional criteria performed during apparatus catch only. Therefore, the additional criteria of throw are more used in hoop and clubs routines, and the criteria of catch of apparatus in hoop and ball routines.

Pearson Correlation

Through of Pearson Correlation (Table 5) were found the significant correlations between variables of study. The positive correlations show that these variables favor the final score, and the negative correlations mean that the increase in the number of these variables reflects negatively on the respective score.

Increases in the number of additional criteria of body rotations in imply a decrease in the gymnasts' final score. Routines with higher number of masteries with NFGE, departure difficulty score and difficulty score in the competition presented higher final scores.

Table 3

Number of masteries elements with fundamental and non-fundamental group elements in Rhythmic Gymnastics routines clustered according to their ranking position.

Apparatus	Ranking groups	Total Number M			Number M with FGE (x±sd)	Number M with NFGE (x±sd)
		Min	Max	x±sd		
General (all apparatus)	Finalists (n=64)	2	8	4.31±1.56	2.11*±1.93	2.52*±1.14
	2nd Group (n=112)	1	10	4.14±1.95	2.22±2.09	2.30±1.24
	3rd Group (n=112)	0	13	4.57±2.71	2.78*±2.33	2.02*±1.22
Hoop	Finalists (n=16)	3	7	4.56±0.96	2.81±1.64	2.56*±1.03
	2nd Group (n=28)	2	10	5.04±1.77	3.54±1.93	2.11±0.92
	3rd Group (n=28)	1	10	4.54±2.32	3.46±2.20	1.46*±1.04
Ball	Finalists (n=16)	4	8	5.88±1.26	3.94±1.73	2.19±1.33
	2nd Group (n=28)	2	10	5.21±2.10	3.50±1.93	1.96±1.23
	3rd Group (n=28)	1	13	6.32±3.38	4.14±2.55	2.32±1.39
Clubs	Finalists (n=16)	2	6	3.63±1.15	0.88*±0.96	2.88±1.15
	2nd Group (n=28)	1	6	3.54±1.32	0.71*±0.94	2.93±1.25
	3rd Group (n=28)	0	10	3.93±2.05	1,71*±1.49	2.25±1.18
Ribbon	Finalists (n=16)	2	6	3.19±1.38	0.81±1.28	2.44±1.03
	2nd Group (n=28)	1	6	2.79±1.42	1.14±1.60	2.21±1.37
	3rd Group (n=28)	1	9	3.50±2.11	1.79±2.04	2.04±1.10

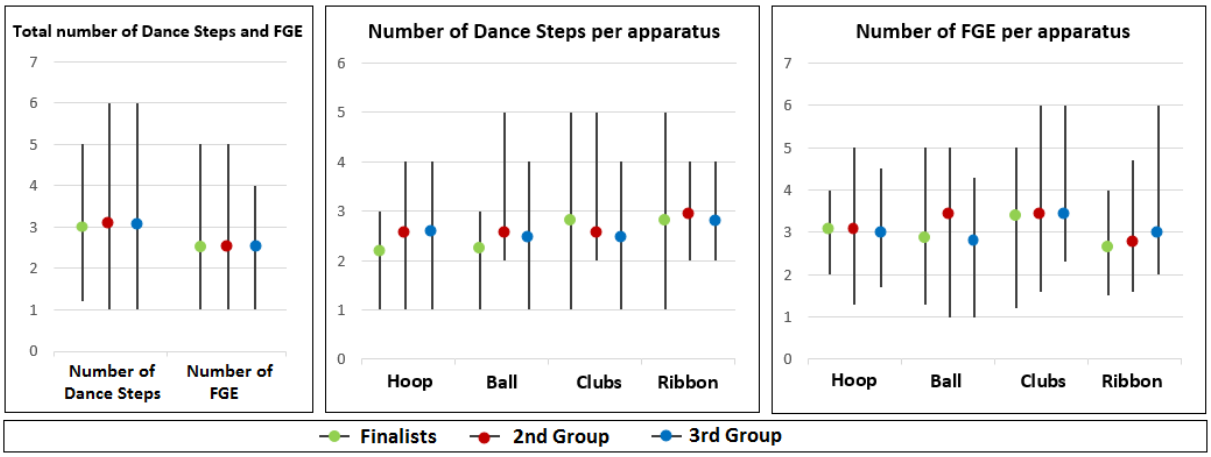

Figure 1. Dance steps data presented in the Rhythmic Gymnastics routines clustered according to their ranking position.

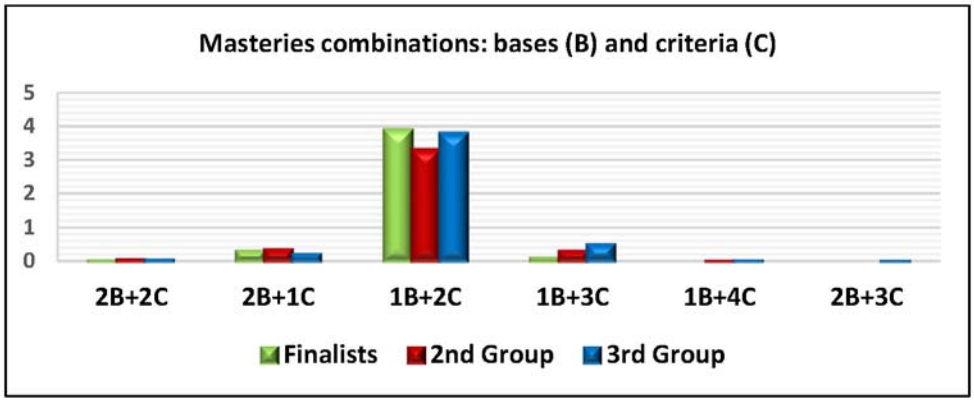

Figure 2. Combinations of bases and criteria in masteries in Rhythmic Gymnastics routines clustered according to their ranking position.

Table 4

Number of rotations and additional criteria performed in the DER per apparatus in the Rhythmic Gymnastics routines clustered according to their ranking position.

Apparatus	Ranking groups	Nº Rotations (x±sd)	Total nº add criteria (x±sd)	Nº add criteria Throw (x±sd)	Nº add criteria BD (x±sd)	Nº add criteria Catch (x±sd)
Hoop	Finalists (n=16)	3.12±0.49	4.25±1.05	1.02±0.55	1.38±0.74	1.85±0.49
	2nd Group (n=28)	3.24±0.39	4.42±0.84	1.27±0.1	1.66±0.61	1.49±0.65
	3rd Group (n=28)	3.10±0.43	4.25±0.73	1.04±0.50	1.67±0.57	1.55±0.60
Ball	Finalists (n=16)	3.04±0.34	3.19±0.70	0.33±0.32	1.54±0.74	1.31±0.65
	2nd Group (n=28)	3.16±0.33	2.91±0.61	0.29±0.31	1.51±0.52	1.11±0.51
	3rd Group (n=28)	3.07±0.52	3.29±0.81	0.37±0.29	1.74±0.76	1,18±0.58
Clubs	Finalists (n=16)	3.19±0.32	4.21±0.47	1.67±0.52	1.73±0.56	0.81±0.50
	2nd Group (n=28)	3.35±0.39	3.85±0.93	1.33±0.59	1.81±0.64	0.70±0.58
	3rd Group (n=28)	3.27±0.37	3.92±0.90	1.30±0.51	1.89±0.55	0.73±0.51
Ribbon	Finalists (n=16)	3.69±0.31	3.02±0.71	0.73±0.39	1.81±0.61	0.48±0.60
	2nd Group (n=28)	3.54±0.38	3.19±0.66	0.73±0.34	2.02±0.51	0.44±0.43
	3rd Group (n=28)	3.39±0.54	3.00±0.93	0.75±0.47	1.92±0.66	0.33±0.41

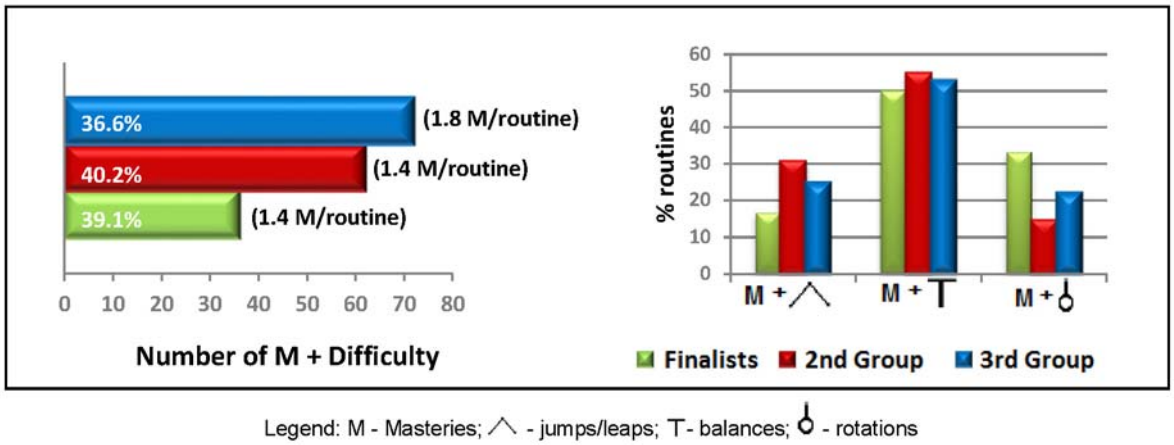

Figure 3. Masteries performed during a body difficulty elements in the Rhythmic Gymnastics routines clustered according to their ranking position.

Table 5

Pearson correlations – dependent and independents variables.

Dependent Variable	Independent Variables	Proof value	Pearson Correlation
Final Score in the competition	Nº Masteries with NFGE	p=0.002*	0.184
	Nº add criteria of body rotation (DER)	p=0.002*	-0.190
	Departure difficulty score	p≤0.001*	0.540
	Difficulty Score in competition	p≤0.001*	0.962

Legend: NFGE – non-fundamental groups apparatus elements; DER – dynamic elements with rotation and throw; * p ≤0.05: Significant differences

DISCUSSION

At every 4 years, at the end of the Olympic cycle, the RG-CoP changes and as a consequence of the constant and quick evolution of this sport, a permanent upgrade of studies about the composition of competition routines in RG are essential to know the direction in which RG is evolving (Bucar et al., 2013; Caburrasi & Santana, 2003; Čuk et al., 2012; Hökelmann et al., 2012; Massidda & Calò, 2012; Pelin, 2013).

Dance steps

The groups analyzed presented similar characteristics for the dance steps: similar number of dance steps and FGE performed. Therefore, these results showed that the main characteristics of the dance steps presented in the competition routines do not differ the gymnasts according to the ranking position, but the number of validated dance steps by the judges can differentiate them. However, Leandro et al. (2015) verified significant differences in agreement and disagreement on the dance steps evaluation between judges, demonstrating a high variability in the evaluation, probably due to lack of precision in the type of evaluation proposed by the RG-CoP. The authors explain that the dance steps have as criteria to be validate, the duration of at least 8 seconds, evaluated without a stopwatch or other device, but through the sensibility of the judge, and can be serious influenced by the music rhythm.

Leandro et al. (2015) recommend that the RG-CoP should include more precise definitions of the technical requirements. Simões (2000) explains that precise criteria allow a correct judgment of performance, due to the possibility of be understood equally by the various evaluators.

We observed that all groups presented a higher number of dance steps in ribbon routines, probably because of the deformable characteristics of the apparatus and the dance steps can bring greater beauty to the compositions. And also, perhaps, due to the length of the ribbon, the gymnasts have to maintain themselves in movement during the all routine duration to avoid the end of ribbon to touch the floor and consequent penalization (FIG, 2012). Therefore, they could choose the dance steps as a way to improve the continuous movement of this apparatus. The clubs routines had the higher number of FGE in each dance step in all groups analyzed, probably because the FGE in these apparatus are technical elements performed with a fast execution. So the gymnast can perform a higher number of apparatus movements in dance steps, showing apparatus mastery. The inclusion of complex abilities in the routines is essential to have a high score in the competition (Massidda & Calò, 2012).

Masteries

A similar number of masteries were found in all groups. As in dance steps, these results suggest that the number of the masteries presented in the gymnasts' official Difficulty forms do not differentiate the gymnasts according to the ranking position. However, we observed that the 3rd group presented a higher number of masteries than the remaining groups and this ranking position also showed a high range in number of masteries. In the finalists' routines we verified a lower number of masteries. We believe that these results can be motivated for two reasons. The best gymnasts normally present better physical and artistic capacities for the sport, which allows them to perform more and higher level elements with complex execution (Bobo & Sierra, 2006), while the less able gymnasts can resort to the masteries elements that depends especially on coordination, to increase the difficulty value of their routines. Furthermore, the higher number of masteries can be justified by lack of precision of the rules in RG-CoP (FIG, 2012) for these elements: the mastery must be unique and extraordinary because they are not performed on a regular basis as standard apparatus movements in RG. The masteries are complex apparatus handling and probably, several proposed elements in the official Difficulty forms were not considered by the judges as masteries. So we believe that the number of valid masteries elements executed without faults can also differentiate the gymnasts. However, according to Leandro et al. (2015) the masteries evaluation has a high disagreement between judges (62.5%). For the authors, the definition of

"extraordinary apparatus elements" presented in RG-CoP is vague to allow an accurate evaluate and could be also influenced by the international experience of the judges.

Therefore, the preference for the use of masteries can be part of justification of low results in 3rd group. The routines (ball, clubs and ribbon) of this group had more number of masteries. Probably, these gymnasts present a high departure difficulty score with elements that, in reality, they can not to perform correctly. There is an overvaluation of departure score and there is not a direct relationship to real performance capabilities of the gymnast (Leandro et al., 2016a).

We observed that in all groups analyzed there is a higher number of masteries in ball and hoop routines. We can also speculate that in ribbon and clubs routines the gymnasts invest more in dance steps than in masteries due the more execution difficulty in these apparatus and, probably, the opposite happens in ball and hoop routines.

The mastery consists of, at least, 1 base (1B) – FGE and/or NFGE, plus a minimum 2 criteria (2C). Or 2 bases (2B) plus minimum 1 criteria (1C). Although we observed 6 different combinations of bases and criteria, the most routines presented the combination 1 base plus 2 criteria, probably because this is the easiest combination of bases and criteria required by the RG-CoP.

Through the analysis we also found that the higher the ranking position, higher the number of NFGE and lower the number of FGE used in masteries. Therefore, the finalists showed more NFGE and less FGE in masteries than the other groups analyzed. The NFGE more used in masteries were apparatus handling, throws and catches in all apparatus. The routines of the lower ranking position had a higher number of masteries with FGE than finalists in all apparatus routines.

The masteries are spectacular elements (FIG, 2012) and when performed during body difficulty they become more complex to execute without faults. The results found showed that the lower the ranking position, higher the number of masteries in body difficulty elements per routine. Considering only the data of competitive routines with masteries in body difficulty elements, we observed 1.4 masteries in body difficulty elements per finalist and 2nd group routine, while a higher number of masteries in body difficulty (1.8) was verified per 3rd group routine. These data also can probably be one of the justifications for the ranking position.

According to Leandro et al. (2016a), rotations, masteries and DER have a higher contribution to the difference between departure and final difficulty score, due the more possibilities of technical faults which cancel the value of the difficulty, mainly the weaker gymnasts. These complex difficulty elements demand a lot of training hours, a singular coordination and high apparatus technical domain (Vitrichenko et al., 2011). To obtain top scores, the gymnasts should present routines with a high difficulty level combined with good performance quality (Agopyan, 2014). The inferior execution quality of middle and lower ranked gymnasts suggest that the coaches do not have a real perception of the performance capacity of their gymnasts in these types of difficulty elements (Leandro et al., 2016a).

Dynamic elements with Rotation and throw (DER)

DER are complex elements with body rotations during the fly of the apparatus. All groups analyzed presented the maximum number of DER in routines with similar number of criteria. These results suggest that the characteristics of DER presented in the gymnasts' official Difficulty forms also do not discriminate the ranking position. However, the number of valid DER or valid criteria can cause a distinction between the gymnasts. Leandro et al. (2016a) verified a high difference in

the departure and final difficulty score in DER elements in different ranking groups analyzed, although this difference increases as the gymnasts go lower in the ranking.

Through the analysis, we observed that for all groups, the lower the weight of apparatus, higher the body rotations number in DER performed in the routines. The weight of apparatus according to the Apparatus Norm (FIG, 2016) is the following: ribbon (35g minimum without the cane); clubs (150g minimum each); hoop (300g minimum) and ball (400g minimum). In the additional criteria performed during the throw of the apparatus, the groups analyzed presented lower results in ball and ribbon routines, and higher results in clubs and hoop routines; these differences are probably justified by the higher number of specific additional criteria in clubs and hoop routines presented in the RG-CoP (FIG, 2012). There are nine different types of additional criteria of throw (Table 3) in DER, however, 77.8% of these criteria can be used in clubs and hoop routines, while 44.3% in ball and ribbon routines. Furthermore, in the additional criteria performed during the catch of the apparatus, we observed that the gymnasts presented higher results in hoop and ball routines, and lower results in clubs and ribbon routines. Equally, we believe that the higher number of specific additional criteria in hoop and ball routines presented in the RG-CoP (FIG, 2012) explains this difference. There are nine different types of additional criteria of catch (Table 3) in DER, however, 77.8% of these criteria can be used in hoop and ball routines, while 66.8% in clubs and ribbon routines.

Similarly to the study by Leandro et al. (2016b), the most used criteria in DER were: "change of level", "change of body rotation axis", "throw/catch outside of visual control" and "throw/catch without the help of the hands".

Pearson Correlation

The small number of significant correlations among the analyzed variables is justified probably because the gymnasts have similar characteristics in all difficulty elements presented in the routines. However, we highlight the positive correlation between the masteries with NFGE and the final scores. The apparatus elements (NFGE) more used were the throw and catch of the apparatus.

CONCLUSION

The groups analyzed (finalists, 2nd and 3rd group) presented similar number of difficulty elements (dance steps, masteries and DER) in the official Difficulty forms in all apparatus. Furthermore, the difficulty level also was similar in the dance steps and DER. The similarity observed in these difficulty elements studied in the composition of routines in different apparatus in RG can compromise the originality and variety of this sport. As we only have access to the official Difficulty forms delivered by the coaches and not evaluated by the judges, we believe that the real differences in the groups reside mostly in the validation or invalidation by the judges of the difficulty elements presented in the official Difficulty forms and in the execution quality of the gymnasts in competition.

The best gymnasts (finalists) and the remaining groups showed routines with some different characteristics although without statistical significance, especially in the masteries elements. We observed that the higher of the ranking position, lower the number of combinations of base and criteria in the masteries, higher the number of NFGE and lower the number of FGE in the masteries. The routines with worse results in the competition presented high data range and higher number of masteries. Therefore, it seems that the coaches of the best gymnasts are more realistic in intention to accomplish the requirement and complexity of the

elements inscribed on the Difficulty official forms.

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GENDER INEQUALITIES IN PORTUGUESE GYMNASTS BETWEEN 2012 AND 2016

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Original article

Abstract

Gender participation rates are different and the potential reasons are namely sports availability and stereotypes. In spite of gymnastics being recently considered as an "early specialization" sport, characterized by a higher number of female participants than male ones, it has been highlighted that there are much less published studies in female athletes than in males. The aim of this study was to analyze the gender participation among Portuguese gymnasts according to gymnastics' disciplines. An individual authorized database of all national gymnasts involved in the National School of Gymnastics of the Gymnastics Federation of Portugal among four athletic seasons, namely 2012/2013,2013/2014, 2014/2015 and 2015/2016 was used. From a sample of 14,742 gymnasts, 81.3% were female and only 18.7% were male($P<0.01$) during the athletic season of 2012/2013. Similar results were found in the next three seasons as follows: 83.3% females and 16.7% males in 2013/2014, 84.9% females and 15.1% males in 2014/2015 and 85.3% females and 14.7% males in 2015/2016. Significantly gymnasts-gender differences($P<0.01$) were observed for all disciplines. No differences between genders were observed in Rhythmic Gymnastics, Women's Artistic Gymnastics and Men's Artistic Gymnastics due to the exclusive sport participation of female and male gymnasts, respectively. Gymnastics should improve participation and combat gender inequalities.

Keywords: *gymnastics, gender participation, athletes, disciplines.*

INTRODUCTION

One of the 'Fundamental Principles of Olympism' is that "Any form of discrimination with regard to a country or a person on the grounds of race, religion, politics, gender or otherwise is incompatible with belonging to the Olympic Movement" (International Olympic Committee, 2011). However, gender has been considered a significant indicator of athletic performance's differences and gender participation rates are different and the potential reasons are

namely sports availability and stereotypes (Davis et al., 2006).

Several physical and psychological benefits, namely increased resistance, strength, agility, coordination and improved mood, self-esteem and self-confidence are responsible for sports participation (Slater & Tiggemann, 2011).

Gymnastics is well-known by its aesthetic character that emphasizes creativity and athlete's peak of performance typically obtained earlier than in team sports (Baker, Janning, Wong, Cobley, & Schorer, 2014), since gymnasts train intensively from very young ages and maintain that training regime during adolescence and early adulthood (Silva & Paiva, 2015a, 2016). In children (from 2 to 10 years old), pubertal growth is linear and occurs at a relatively constant rate (6 cm per year) (Jeukendrup & Cronin, 2011). However, in adolescence, significant changes in body size occur, influencing physiological and physical performance (Silva & Paiva, 2015a) in both female and male gymnasts (i.e., males tend to have more fat-free mass and a lower body fat than females).

In addition, leanness is also a valuable prerequisite for technical performance and is considered more aesthetically pleasing to judges and for selection at an elite level (D'Alessandro et al., 2007; Michopoulou et al., 2011; Silva & Paiva, 2016; Silva & Barata, 2016). However, and as highlighted by recent studies conducted by Silva and Paiva (2015a, 2016) in elite female gymnasts, a reduced body mass often leads gymnasts to inadequate energy intake, compromising adequate energy availability levels for gymnasts' growth, daily activities and athletic performance.

In spite of gymnastics being recently considered as an "early specialization" sport, characterized by a higher number of female participants than males (Baker et al., 2014), McManus and Armstrong (2011) highlighted that there are much less published studies in female athletes than in males.

In the short-term, energy availability is required to improve gymnasts' health, to prevent injury and, in the long-term, sustained low energy availability may predispose the female athletes to various health hazards such as irregular menstruation, infertility and osteoporosis (Loucks, Kiens, & Wright, 2011; Omiya et al., 2014; Silva & Paiva, 2015a, 2015b). Thus, female athletes may be a more difficult group to study, especially in relation to health issues, including body composition and menstrual function, than male athletes.

On the other hand, the cultural environment and regional tradition in a typical sport also influences sport participation (Weir, Smith, Paterson, & Horton, 2010). In addition, gender is a socially category constructed in the interaction between the individual and the society and self-actualization (Boykoff & Yasuoka, 2013).

In accordance with the International Federation of Gymnastics (*Fédération Internationale de Gymnastique* – FIG, 2015), gymnastics is divided into seven disciplines: Gymnastics for All (GfA), Men's Artistic Gymnastics (MAG), Women's Artistic Gymnastics (WAG), Rhythmic Gymnastics (RG), Trampoline Gymnastics (TRA), Aerobic Gymnastics (AER) and Acrobatic Gymnastics (ACRO).

Apart from gymnastics' discipline and gymnast's gender, competitive routines result from a combination of several different body elements that require high-intensity effort with, in some cases, a unique dexterous manipulation of apparatus (Silva & Paiva, 2015a; Silva & Barata, 2016). Dynamic and static balance is important in balance positions, jumps and rotations; explosive strength is necessary for dynamic elements with rotation and throw, jumps and pre-acrobatic movements; flexibility is dominant during all body elements; and coordination is crucial for apparatus

mastery (Calavalle et al., 2008; Silva & Paiva, 2015a).

Therefore, this study aims to be an extension of the published study by Silva and Barata (2016) by analyzing the gender participation among Portuguese gymnasts according to gymnastics' disciplines.

METHODS

During the sport season of 2012/2013, 14,742 Portuguese gymnasts (11,975 female and 2,767 male) were included in this study. Also from the next three athletic seasons, 15,880 gymnasts (13,225 female and 2,655 male) in 2013/2014, 15,469 gymnasts (13,139 female and 2,330 male) in 2014/2015 and 16,442 gymnasts (13,660 female and 2,782 male) were included.

Data was analyzed from an individual authorized database of all national gymnasts involved in the National School of Gymnastics of the Gymnastics Federation of Portugal (*Federação de Ginástica de Portugal* – FGP) among four athletic seasons, namely 2012/2013,2013/2014, 2014/2015, and 2015/2016.

This database was constructed by the technical staff of the general directorate office of the FGP and formal permission for full access to the mentioned database was given by the director of the National School of Gymnastics of the FGP.

Regarding gymnastics' disciplines, the FGP involves seven international disciplines mentioned before and two others, such as Teamgym (TG), a *Union Européenne de Gymnastique* (UEG) discipline that promotes group gymnastics competition and Hip Hop (HH) (organizing Open competitions and the National Championship Competition). Thus, disciplines analyzed were as follows: GfA, MAG, WAG, RG, TRA, AER, ACRO, TG and HH. Therefore, gender participation and the represented gymnastics' discipline were then analyzed.

Regarding the statistical analysis, characteristics of the participants are described with proportions for categorical variables. Spearman correlation coefficient was used to determine associations between categorical and continuous variables; due to the number of subjects evaluated the significance level used was 5% ($p<0.05$). Data was analyzed using SPSS statistical software version 22.0 for Windows (New York, USA).

RESULTS

GfA was the most practiced gymnastics' discipline in Portugal ($P<0.01$) during all sport seasons (Figure 1), since it is so-called "for all" due to the possibility of participants of both genders being able to participate it.

Following GfA, there were TRA and ACRO ($P<0.05$), with exception for the last two sport seasons of 2014/2015 and 2015/2016 ($P>0.05$), where more participants were involved in ACRO rather than in TRA.

All others disciplines were highly less practiced as follows: RG, WAG, TG, AER, MAG and HH (Figure 1).

T-tests indicated significant differences ($P<0.05$) in Portuguese gymnasts' gender-participation during the four evaluated sport seasons.

From a sample of 14,742 gymnasts in the athletic season of 2012/2013, 81.3% were female and only 18.7% were male.

Similar results were found in the next three seasons as follows: 83.3% females and 16.7% males in 2013/2014, 84.9% females and 15.1% males in 2014/2015 and 85.3% females and 14.7% males in 2015/2016.

Significantly gymnasts-gender differences ($P<0.01$) were observed for all disciplines; however, in RG, WAG and MAG, no significant differences were observed due to the exclusive sport participation of female or male gymnasts, respectively.

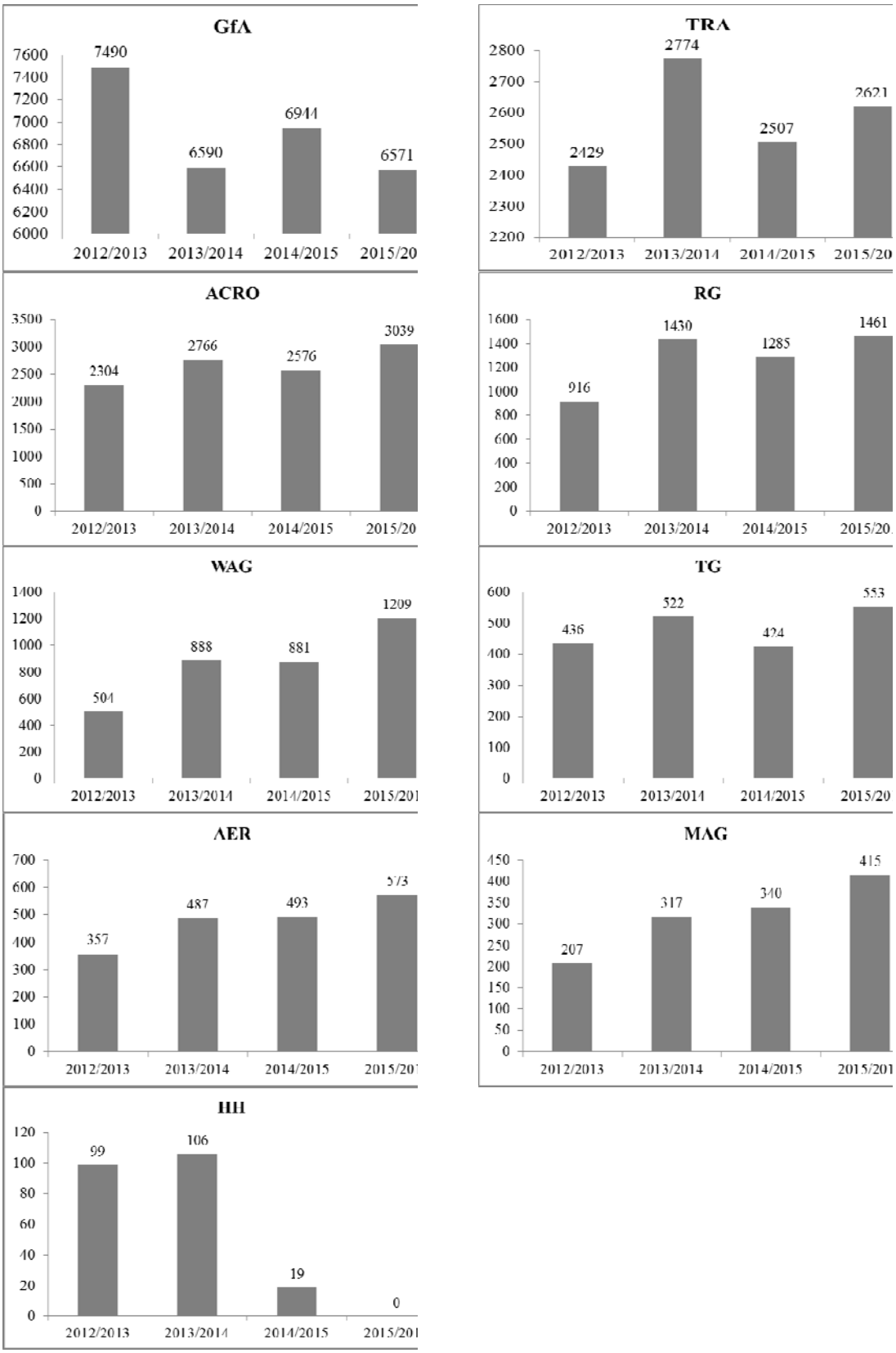

Figure 1. Number of gymnasts participating in the several disciplines of the FGP during the seasons of 2012/2013, 2013/2014, 2014/2015 and 2015/2016 (GfA: Gymnastics for All. TRA: Trampoline Gymnastics. ACRO: Acrobatic Gymnastics. RG: Rhythmic Gymnastics. WAG: Women's Artistic Gymnastics. TG: Teamgym. AER: Aerobic Gymnastics. MAG: Men's Artistic Gymnastics. HH: Hip Hop).

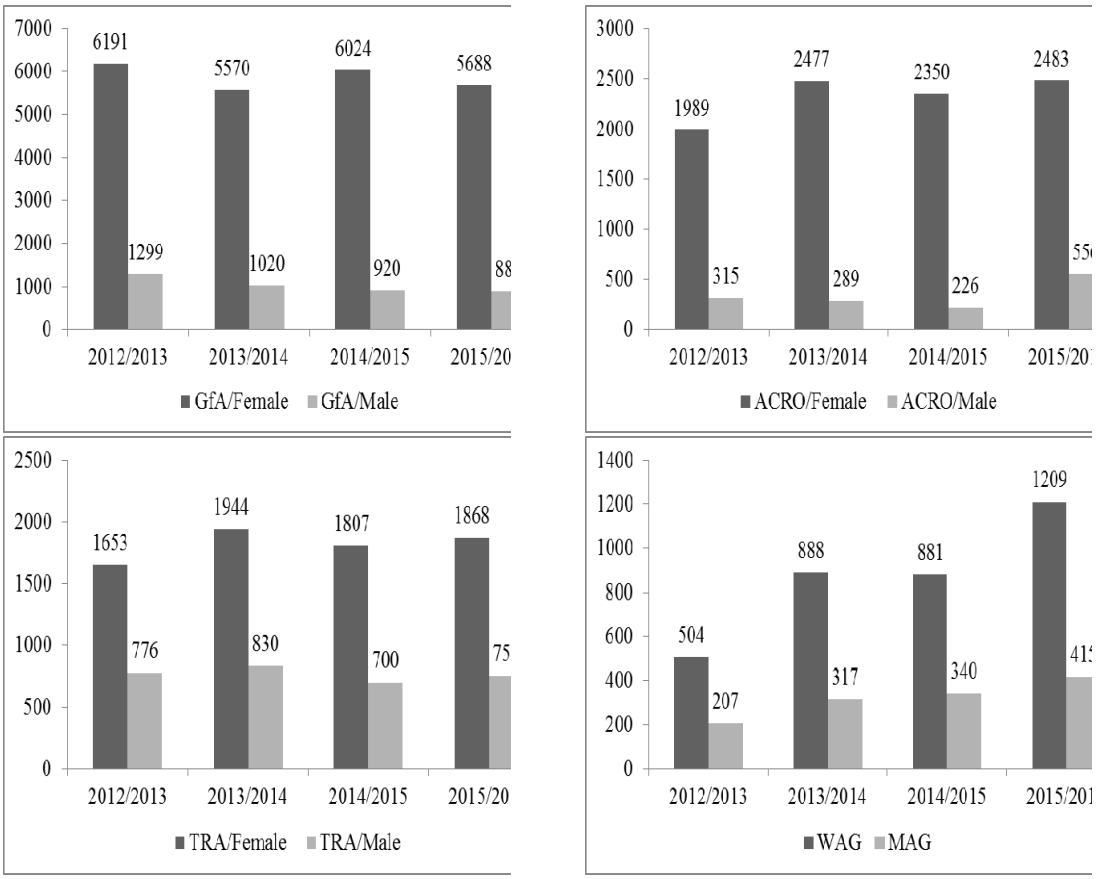

Figure 2. Gender participation in the most practiced disciplines of the FGP during four athletic seasons: 2012/2013, 2013/2014, 2014/2015 and 2015/2016 (GfA: Gymnastics for All. ACRO: Acrobatic Gymnastics. TRA: Trampoline Gymnastics. WAG: Women's Artistic Gymnastics).

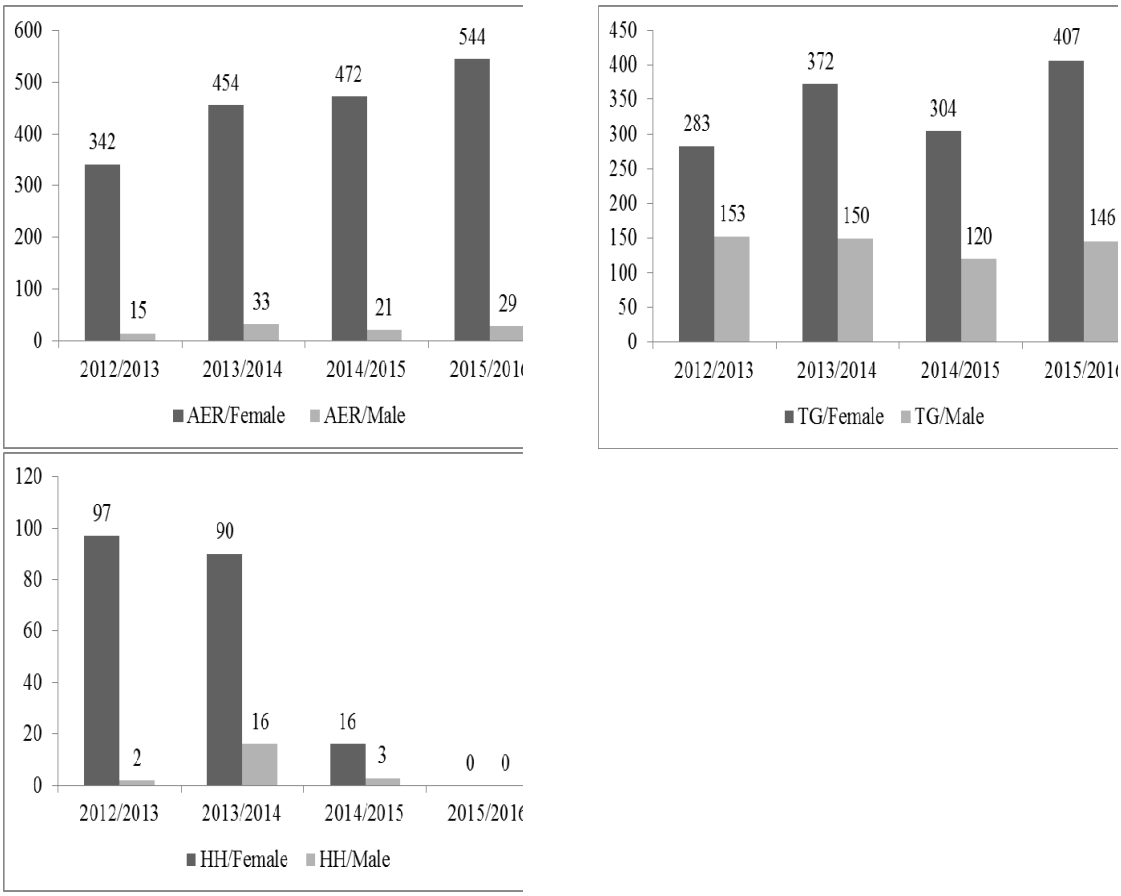

Figure 3. Gender participation in the less practiced disciplines of the FGP during four athletic seasons: 2012/2013, 2013/2014, 2014/2015 and 2015/2016 (AER: Aerobic Gymnastics. TG: Teamgym. HH: Hip Hop).

Curiously, in an intra-athletic season analysis, the athletic season of 2014/2015 was significantly (P<0.05) the worst of all athletic seasons with regard to male participation, since it was observed a decrease in gymnasts participation in all disciplines, with exception for MAG (n=340), and for AER (n=15) in 2012/2013 (Figures 2 and 3).

Although the situation is not so worrying about female gymnasts, because of their ascending participation from the beginning of this study, also the athletic season of 2014/2015 and the first evaluated season (2012/2013) demonstrated the lowest numbers of female participation in all disciplines, with exception for GfA, AER and HH; in the latter, a great decrease (over 80%) was observed from 2013/2014 to 2014/2015 (Figures 2 and 3).

Fortunately, male participation increased in the last season for almost all disciplines, except in the most practiced discipline in Portugal, that is GfA (n=883), and in the less practiced, the HH, which did not have any male or female gymnast participation in the season of 2015/2016 (Figures 2 and 3). In fact, in 2015/2016, male participation increased significantly in ACRO (P=0.000) and female participation also increased significantly in WAG (P=0.023), AER (P=0.041) and TG (P=0.025).

DISCUSSION

Although this study is an extension of a previous one, published in this scientific journal (Silva & Barata, 2016), some important and recent indicators about

Portuguese gymnasts' participation during the last four athletic seasons have been demonstrated, including the recent sport season of 2015/2016.

Several studies have been conducted in athletes regarding physiology, biomechanics, psychology, but most of them are reported to males. Therefore, and from our best knowledge, this is one of the very few studies evaluating gender participation in gymnastics.

The former president of the International Olympic Committee (IOC), Jacques Rogge (2012) highlighted at the Games Opening Ceremony that "For the first time in Olympic history, all the participating teams will have had female athletes, and this is a major boost for gender equality". In fact, Donnelly and Donnelly (2013) reported that 4,835 female athletes participated in the 2012 London Olympic Games, no countries excluded female athletes and women competed in every sport. Contrarily, Boykoff and Yasuoka (2013) concluded that in the London 2012 Olympics, there were 39 men-only events, including the pommel horse and rings in gymnastics, and only two women-only events, such as RG and synchronized swimming.

In our study, significantly gender differences ($P<0.01$) were observed for all disciplines with a female participation's rate much higher than the male one.

As expected, no differences between genders were observed for RG, WAG and MAG due to the exclusive sport participation of female or male gymnasts, respectively.

Although the still most practiced discipline in Portugal is GfA, where gender selection is not a prerequisite for sport's participation, its prevalence decreased in the last season of 2015/2016, contrarily to Barker, Barker-Ruchti, Wals and Tinning (2014), and Silva and Paiva (2016), who concluded that most athletes choose to persist with competitive sport voluntarily. Thus, more research has to be done in the next sport seasons in order to clarify this evolution.

After GfA, TRA and ACRO were the most practiced disciplines in Portugal, but a recent change was observed in 2015/2016 with ACRO's participants overstepping TRA's participants. In fact, ACRO has a growing number of participants worldwide (Grapton, Lion, Gauchard, Barrault, & Perrin, 2013) and Portuguese acrobatic gymnasts seem to be included in this general trend. On the other hand, HH had no participants, being female or male, so this should be weighed by Portuguese local associations and the FGP.

Although the Olympic Movement (International Olympic Committee, 2011) states the need to achieve equality between men and women in sport at all levels and in all structures, a new challenge stands up for the sport worldwide, which is that there is a clear inequality of gender participation in gymnastics, reflected in our results, since Portuguese female gymnasts showed a high and significant presence in the Portuguese Gymnastics ($P<0.05$). This should be interpreted as part of a solution for the so-called "gender inequality in sport", according to recent literature (Baker et al., 2014; Claringbould, Knoppers & Jacobs, 2015; Di Cagno et al., 2009; Godoy-Pressland & Griggs, 2014; Mackintosh, Darko, Rutherford, & Wilkins, 2014). A plausible explanation might be related to the dominant gender in the social system around gymnastics, i.e., female sport produces a different environment governed by distinct social and developmental factors than those important in male sport (Barker et al., 2014).

On the other hand, political and social time may be an important constraint to gymnastics' practice in Portugal, because athletic seasons of 2012/2013 and 2014/2015 demonstrated the lowest numbers of female participation in all disciplines, with exception for GfA, AER and HH; and, in turn, the athletic season of

2014/2015 was the worst of all athletic seasons with regard to male participation, showing a decrease in all disciplines, with exception for MAG. Therefore, may be the social and economic situation of Portuguese families in those periods of time was not favorable for sport practice (Schubring & Thiel, 2014). Portugal was, and still is, in a terrible socio-economic crisis, which might influence gymnasts sport practice.

Moreover, Weir and colleagues (2010) in a study about the age of sport participation concluded that the number of sport participants might vary due to the cultural importance of different sports with the most capable athletes, the relatively older ones going to sports with the greatest cultural relevance. In addition to physical and cognitive demands, gymnasts should also integrate a high degree of technical (Barker et al., 2014) and artistic skills into their dynamic and aesthetic exercises (Di Cagno et al., 2009).

On the other hand, gymnastics is known to be the oldest sport ever practiced and is often sought to be the better sport to develop physical and mentally the "raw material" at very young ages (Baker et al., 2014; Silva & Paiva, 2015a).

Although not significantly, Portuguese female gymnasts' participation only increased in GfA and AER in the last athletic season, and the same was demonstrated by male participants in MAG.

Considering that when gymnasts are relatively older, they transfer to other sports (Barker et al, 2014) and that a combination of factors might be responsible for that (Omiya et al., 2014), a problem stands up for the FGP. As mentioned before, age was not available for this study, but it might have a major influence in sport participation (Silva & Barata, 2016).

Education sessions to increase future gymnasts' participation should be implemented as a new perspective of increasing both female and male participation in geographical areas with fewer participants.

The limitations of this study should be taken into account when interpreting these results. First, age was not a studied variable. Although its relative effects have been studied (Schorer, Cobley, Büsch, Bräutigam, & Baker, 2009), we assumed that gymnastics' disciplines would be of greater interest for this publication. Longitudinal studies are being implemented in the FGP in order to study the possible relation between the prevalence of a specific gymnastics' discipline according to the geographic area and gymnasts' results in national and international competitions. They would also be interesting and necessary in evaluating gymnastics' evolution in relation to gender, relative age effects and sport participation.

This study adds additional light on the social, economic and cultural influence of the global economic crisis for sport participation of Portuguese gymnasts, and provides a new insight to reinforce the practice of gymnastics worldwide, in accordance with significant differences between female and male's participation. Gymnastics should be studied and used as a sport capable of improving participation and combat gender inequalities.

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COMPARISON OF MORPHOLOGICAL CHARACTERISTICS OF TOP LEVEL MALE GYMNASTS BETWEEN THE YEARS OF 2000 AND 2015

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Original article

Abstract

Over the years gymnastics is changing, difficulty of the routines is improving, the technology and the equipment are developing, Code of Points (COP) is getting new aspects. In 15 years, from the year of 2000 to 2015 COP changed a lot. Two measurements of morphological characteristics of top level male gymnasts were taken and compared, one from the year of 2000 and one from 2015, both from a World Cup Competition in Ljubljana. Our study showed some significant differences in abdomen circumferences and percentage of muscle mass of gymnasts in 15 years. Despite there were no significant differences, the tendency is the increase in body height, with less percentage of body fat and percentage of muscle mass (with the exception of gymnasts competing on floor). With lower percentage of body fat, lower percentage of muscle mass and almost unchanged body weight we can presume bone mass probably increased and with tendency of taller gymnasts also other inner organs, increased weight.

Keywords*: male artistic gymnastics, Code of Points, morphological characteristics, differences.*

INTRODUCTION

Gymnastics as a sport has quite a long history (the first World Championship was organized in 1903 in Antwerpen, Netherlands), and as years are passing, the competition program is changing. In the mid-30s of the previous century, the male gymnastics program was already quite similar to what we have today. Gymnasts competed in Free Program ('floor' today), Pommel Horse, Rings, Vault, Parallel Bars and High Bar, both in the compulsory and optional program (Štukelj, 1989). These days, a program in Men's Artistic Gymnastics consists only of free program on various apparatus, which are the same as back then (FIG, 2016).

The competition program is similar, but rules in Men's Artistic Gymnastics changed a lot in the last 15 years. Some parts of the COP 1997-2000 and COP 2013-2016 are even hard to compare. The most visible change is the calculation of the Final Score. In the year of 2000 the maximal score was 10.00 points (that changed in the 2006 COP (FIG, 2006)). The Score was calculated from the "B"

Score – score of execution, which was maximum 5.00 points and the "A" Score, which consisted of difficulty value, special requirements on each apparatus and bonus points (for executing difficult elements and connections of them), also maximum 5.00 points. From the year of 2006 on, the final score is calculated from "D" Score for Difficulty and "E" Score for Execution. "E" Score, starts from 10.00 points and is evaluated by deductions (the exercise presentation related to compositional requirements, technique and body position) applied in tenths of a point. In general deductions are much more defined in 2015 than they were in 2000; the level of precise errors (for deviations from the expected perfect performance) remains mostly the same though. Small, medium, large errors and falls are deducted differently in the 15 years difference (the small deduction remains the same, the medium error changes from 0.2 to 0.3 point, the large error from 0.4 to 0.5 points, the deduction for a fall raised up from 0.5 to 1.00 point deduction (FIG, 1997; FIG, 2016)).

In the year of 2000 values of difficulty elements ranged from A to Super E. The difficulty value (on each apparatus except for vault) for elements was up to 2.40 points and was calculated from 4 A (4 x 0.1 point), 3 B (3 x 0.2 points), 2 C (2 x 0.4 points) and 1 D (1 x 0.6 points). There were 3 special requirements on each apparatus (0.4 points each). The gymnasts were awarded with bonus points for execution of difficulty elements and connections of elements with a D, E or Super E values (0.1 or 0.2 points for each connection, depends on the values of the elements). The level of difficulty increased in 15 years, especially in acrobatic elements. In2015 values reach up to H (for example Kovacs with 2/1 twists on high bar, which did not yet exist in 2000 COP) and will include a difficulty value of 10 elements (8 for juniors), the best 9 (7 for juniors), but maximum 4 elements for the same Element Group inside the best counting, plus the value of the dismount. Values of elements are different (from A to H the value is increasing per 0.1 point, which is 0.1 point for A value and 0.8 point for H value). In their routines gymnasts have to include elements from five different groups and for including each element group there is a 0.5 points bonus. For short exercises, where there is not 10 elements shown, the D-Panel jury takes an appropriate neutral deduction (FIG, 2016).

Regarding dismount elements, there was a deduction in 2000 for a dismount difficulty not being corresponding to the difficulty of the exercise. The deduction was 0.1 point for B value dismount, 0.2 points for A value dismount and 0.4 points for no dismount (FIG; 1997). In 2015 the dismount element is part of the Group element requirement. The gymnast achieves a full requirement value of 0.5 points for D or higher value of a dismount, for C value dismount he receives 0.3 points as achieving partial requirement value. For lower difficulty values than C values, the gymnast does not fulfil the requirement (FIG, 2016).

As stated in Čuk et. al (2007) gymnastics saw a major change in its rules in 1997. FIG (1997) abolished compulsory exercises on apparatus. This reduced the need for a large number of hours in training. The same year FIG also introduced World Cup on individual apparatus which enabled gymnasts to further adjust their training to their personal needs and abilities in order to be successful on individual apparatus. Top level gymnasts start with their gymnastics career as very young, usually at preschool age. Today experts believe that the hours of training are about 5-6 hour training sessions. Gymnasts train 1500 hours per year in 300-310 days (Arkaev & Suchilin, 2003), 26-28 hours per week (Georgopoulos et. al, 2011).

The consequences of COP changes for competitors and their preparation can be summarised as follows:

The deduction for fall has increased, compared to previous COP; therefore competitors do not need to risk including an insufficiently mastered element into routine, which was possible in previous code of rules. This leads to a bigger drill based on a higher number of repetitions of learned movement structures. However, it has to be noted that this measure leads to higher exercise safety. Contrary to the rules valid until 2000 when a gymnast had to perform three special requirements in individual disciplines (except for vault), the newer version of the routine must include elements from five groups. Competitors are therefore forced to perform a wider range of different movement structures within the routine, which means that they must be technically and functionally better prepared for individual disciplines.

The change in rules forces competitors to improve technique as well as condition preparation in order to perform the dismount with a full value bonification, C value element for juniors and D value element for seniors.

The above mentioned facts imply that a perfectly acquired technique of complex temporo-spatial structures is an essential factor of gymnastic sport performance. As stated in Prassas et al. (2006), a prerequisite of correctly mastered gymnastic abilities are ability to gain height, ability to rotate, generating twist, transferring angular momentum from one body part to another, increasing or decreasing rotation by altering body configuration, ability to swing and ability to land. These partial abilities are based on understanding and use of various biomechanical principles and patterns which affect the given movement structures at individual equipment.

Kinematic data, while explicitly dependent on technique, is at the same time implicitly dependent on the strength, flexibility, and somatotype of the particular athlete (Kob et al., 2003). It was already at the Olympic Games 1928 in Amsterdam, Netherlands; Bach concluded that shorter persons probably stand a better chance of succeeding in gymnastics while taller persons are more likely to succeed in track and field (Škerlj, 1934). Čuk & Novak (1985) defined successful gymnast as the one who is short (the ratio between the length of trunk and the length of legs should be such that the muscles can quickly move these levers), light and has a strong chest with a relatively high and good quality muscular mass and has a very little subcutaneous fat. According to Arkaev & Suchilin (2003) typical of both men and women modern gymnasts, is ectomorph and ecto-mesomorph type of body composition, moderately wide shoulders, narrow hips, long arms, relatively long legs and short trunk. As stated in Čuk et al. (2007) from the year 1933 up to 2000 gymnast's body height and weight was not changed, but there were changes in shoulders and hips width, where gymnasts in the beginning of the new millennium had wider shoulder and narrower hips, this being a consequence of more complex movements with more rotations around longitudinal and sagittal axis.

Gymnasts that were competing in 2015 had been born in the first years of the 1990's and most likely started to compete around year 2000. At that time rules were different, and their trainings were adjusted to the rules that were in use then. In year 2006 when the open ended COP was introduced, they had to adopt their training within new COP. Therefore, they already had almost 9 years of adaptation time towards COP.

The main purpose of the study is to verify, if with the significant change of rules in the COP between the years, consequently structural change of routines, different deduction procedure and increasing number of specialists on different apparatus have any effect on changing male artistic gymnasts morphological characteristics, specifically body height and weight, the

circumferences of chest, abdomen, upper arms and the percentage of body fat and percentage of muscle mass. We expect some difference in morphological characteristics might follow,

METHODS

We used anthropometric measurements on gymnasts from two different periods, from year 2000 and year 2015. All the measurements were in accordance with Declaration of Helsinki.

The first sample of measured gymnasts consisted of 40 top male competitors, aged between 17 and 30 years (on average 23 years) who participated at World Cup in Ljubljana in 2000 and voluntarily participated in measurements. The measurements took place in Tivoli Hall during trainings before the competition. Gymnasts and their coaches were verbally informed of the purpose of the research, for the measurements they were given the instructions according to Bravničar (1987). Used anthropometrical measurements had been defined by Bravničar (1987). The calculations for percentage of body fat mass, bone mass and muscle mass were made by the devised formula by Mateighka (1933 in Bravničar, 1987). Measurements were carried out by two independent qualified persons. The percentage of body fat mass and percentage of muscle mass were calculated.

Measurements were performed with standard anthropometrical instruments (anthropometer, classic scale, measuring tape and skinfold calliper). Following anthropometric variables were measured:

- body height,
- body weight,
- chest circumference,
- belt circumference,
- upper arm circumferences (left and right),
- thigh circumferences (left and right),
- calf circumferences (left and right)
- triceps skinfold
- biceps skinfold
- forearm skinfold
- thigh skinfold
- calf skinfold
- abdominal skinfold
- chest skinfold
- subscalpula skinfold
- elbow diameter
- wrist diameter
- knee diameter
- ankle diameter

Mateigka (1933 in Bravničar, 1987) devised the formula for calculating the percentage of body fat mass, bone mass and muscle mass by defining skinfolds, circumferences, body mass, body height and diameters.

Body surface area (BSA) was calculated. Then body fat mass was calculated with the following formula:

$$Body\ fat\ mass = c * d * BSA$$

Where "*c*" is the constant of 0,13 and "*d*" is the total value of skinfolds (sum of triceps skinfold, forearm skinfold, thigh skinfold, calf skinfold, abdominal skinfold and chest skinfold, divided by 12).

The percentage of body fat mass was calculated with the following formula:

$$\%\ body\ fat\ mass = \frac{body\ fat\ mass\ (kg) * 100}{body\ mass\ (kg)}$$

The muscle mass (in kg) was calculated from a body height (ABH) and a mean value of the radius of idealized body segments (r):

$$muscle\ mass = 0{,}0065 * ABH * r^2$$

$$r = \frac{ACTR + ACF + ACTH + ACC}{25.12} - \frac{ASFB + ASFF + ASFT + ASFC}{8}$$

ACTR…. triceps circumference
ACF… forearm circumference
ACTH…. thigh circumference
ACC…. calf circumference
ASFB…. biceps skinfold

ASFF…. forearm skinfold
ASFT…. thigh skinfold
ASFC…. calf skinfold

The percentage of muscle mass was calculated from muscle mass (in kg) and body mass (ABM in kg):

$$\%\ muscle\ mass = \frac{muscle\ mass * 100}{ABM}$$

The second sample of measured gymnasts consists of 54 top male competitors, aged between 18 and 37 (on average 24 years) who participated at World Cup in Gymnastics in Ljubljana in 2015 and voluntarily participated in measurements. Gymnasts and their coaches were verbally informed of the purpose of the research. Measurements were taken at the Arena Stožice in Ljubljana, where the World Cup took place. Following anthropometric variables were measured with Inbody720, body height was measured with anthropometer. Measurements were carried out by independent qualified persons (defined by Bravničar 1987 for body height):

- body height
- body weight
- percentage of body fat mass
- percentage of body muscle mass
- belt circumference,
- upper arm circumferences (left and right),thigh circumferences, chest circumferences and percentage of skeletal lean mass were not compared because of the differences in measurement techniques (classic anthropometric measurements and InBody720). Upper arm circumferences are comparable because of the same measurement technique from both years of measurements (in the middle of the elbow and the shoulder), while there was a significant difference between InBody measurements (thighs circumference was measured at 2/3 point of the navel line and knee and chest circumference was measured right under the armpit (InBody User Manual, 1996)) and anthropometrical measurements (thighs circumference was measured under the gluteal fold and chest circumference was measured at the level of nipples).

The results were divided in groups, according to the apparatus they performed on (except for vault, because of not enough competing gymnasts on this apparatus, consequently the lack of data) and compared. BMI for each gymnast was calculated from body height (ABH in m) and body weight (ABM in kg):

$$BMI - \frac{ABM}{(ABH)^2}$$

The measures of an average, standard deviation, F and p(F-test) were calculated for both years. Then the p(t-test) for independent samples was calculated for comparing the groups on the apparatus. All the calculations were made in Microsoft Excel, for p(f-test) the standard tables for F-distribution were used and statistical significance limit for difference was 0,05 (Sagadin, 1982).

RESULTS AND DISCUSSION

At the time that measurements took place, all the gymnasts were past their growth age. Adult height, or near adult height of artistic gymnasts is not compromised by intensive gymnastics training (Malina et. al, 2013).

The average age for our measured groups of competing gymnasts is very similar for both groups between the years; it is 23.7 years old for the year of 2000 and 24.1 years old for the gymnasts in the year of 2015. The slight difference is on the floor in the year of 2000, where gymnasts were slightly younger (21.4 years old). The p(t-test) confirms there's no significant difference (p(t-test) > 0.05). The difference in standard deviation in 2000 is 3,69 years and 4,21 years in 2015, which leads us to a fact that despite no significant difference in average age of gymnasts, the general range of gymnasts age is greater in 2015 that it was in 2000. The difference for the two groups in their birth year is significant (p(t-test) < 0.05) and this proves the measurements were taken with two

different generations of gymnasts in 15 years' time and not one gymnast was measured at both measurements. We can assume the most of gymnasts who competed in 2015 were just in the beginning of their career in 2000.

Table 1
Descriptive statistics of morphological differences of the gymnasts, between the years of 2000 and 2015.

Birth Year [years]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	1978.63	1991.75	1975.29	1990.55	1975.33	1991.06	1976.46	1991.00	1976.81	1990.60
SD	2.43	3.73	4.38	4.42	5.12	4.82	3.31	4.24	3.21	3.86
N	19	20	17	22	9	18	13	20	16	21
F	1.53		1.01		1.06		1.28		1.20	
p(F-test)	2.21		2.31		2.55		2.56		2.33	
p(t-test)	0.000		0.000		0.000		0.000		0.000	
Age [years]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	21.37	23.25	24.71	24.46	24.67	23.94	23.54	24.21	23.19	24.40
SD	2.43	3.73	4.38	4.42	5.12	4.82	3.31	4,24	3.21	3.86
N	19	20	17	22	9	18	13	20	16	21
F	1.53		1.01		1.06		1.28		1.20	
p(F-test)	2.21		2.32		2.55		2.56		2.33	
p(t-test)	0.071		0.861		0.722		0.635		0.321	
Height [cm]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	166.85	170.16	168.94	171.65	163.03	167.37	165.85	168.68	170.79	171.65
SD	5.01	7.08	5.45	7.91	4.16	6.34	4.69	5.82	5.91	6.78
N	19	20	17	22	9	18	13	20	16	21
F	1.41		1.45		1.53		1.24		1.15	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.102		0.234		0.076		0.154		0.693	
Weight [kg]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	66.56	66.79	66.84	68.01	63.86	64.56	63.45	66.45	67.82	68.09
SD	6.32	7.73	7.18	6.97	3.51	6.23	2.94	6.91	6.70	6.81
N	19	20	17	22	9	18	13	20	16	21
F	1.22		1.03		1.78		2.35		1.07	
p(F-test)	2.21		2.15		3.18		2.56		2.20	
p(t-test)	0.919		0.608		0.756		0.153		0.907	
BMI [kg/m^2]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	23.88	23.02	23.37	23.08	24.02	23.04	23.08	23.35	23.21	23.11
SD	1.56	1.71	1.57	1.84	0.82	1.77	0.75	2.11	1.41	1.96
N	19	20	17	22	9	18	13	20	16	21
F	1.09		1.17		2.16		2.83		1.39	
p(F-test)	2.21		2.15		3.18		2.56		2.33	
p(t-test)	0.107		0.610		0.130		0.614		0.855	

Left Arm Circumference [cm]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	33.01	33.36	33.67	33.63	32.81	33.58	33.07	34.44	33.47	34.41
SD	2.34	2.31	1.94	2.14	1.81	3.25	1.81	3.44	2.19	3.08
N	19	20	17	22	9	18	13	20	16	21
F	1.01		1.10		1.79		1.90		1.40	
p(F-test)	2.18		2.31		3.18		2.56		2.33	
p(t-test)	0.642		0.955		0.519		0.199		0.310	
Right Arm Circumference [cm]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	32.81	33.38	33.64	33.62	32.66	33.63	32.98	34.33	33.61	34.39
SD	2.36	2.37	1.76	2.18	1.96	3.03	1.65	3.35	2.29	2.99
N	19	20	17	22	9	18	13	20	16	21
F	1.01		1.24		1.55		2.03		1.31	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.457		0.979		0.392		0.190		0.400	
Abdomen Circumference [cm]										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	77.55	80.11	77.59	80.64	76.61	78.88	75.57	79.94	77.69	80.81
SD	2.83	4.11	3.11	4.42	2.65	3.16	2.25	4.72	3.08	4.77
N	19	20	17	22	9	18	13	20	16	21
F	1.46		1.42		1.94		2.09		1.55	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.030		0.021		0.076		0.004		0.030	
% Body Fat Mass										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	8.59	7.28	7.96	7.20	7.55	6.51	7.34	6.32	8.11	6.48
SD	1.56	3.16	1.18	3.04	1.04	3.20	1.16	2.77	1.59	3.01
N	19	20	17	22	9	18	13	20	16	21
F	2.02		2.58		3.07		2.39		1.89	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.113		0.294		0.355		0.222		0.058	
% Muscle Mass										
	Floor		Pommel Horse		Rings		Parallel Bars		High Bar	
	2000	2015	2000	2015	2000	2015	2000	2015	2000	2015
XA	54.89	60.80	55.34	53.11	54.25	53.58	55.96	53.46	55.80	53.63
SD	2.44	6.66	1.35	1.99	1.68	2.15	2.53	2.30	2.33	2.08
N	19	20	17	22	9	18	13	20	16	21
F	2.74		1.47		1.28		0.91		0.87	
p(F-test)	2.21		2.31		3.18		2.56		2.33	
p(t-test)	0.001		0.000		0.424		0.007		0.005	

No significant difference (p(t-test) > 0.05) is in height according to the averages for each apparatus and altogether. There was also Čuk et. al (2007) who discovered no difference in gymnasts body height between 1933 and 2000, despite the general increase of the human height in the last decades (0.99 cm per a decade note by Johnston & Padez (2009)). Nevertheless the gymnasts tend to be taller in 2015 than in 2000; however the variability is also higher in 2015 than in 2000 and therefore

questionable. The bigger difference is between the tallest and the shortest gymnasts. In 2000 the shortest gymnast was 157.4 cm of height, in 2015 there were two gymnasts with only 150 cm of height. The gymnasts on high bar are the highest in both years, 185.5 cm in 2000 and 183 cm of height in 2015. The difference between the tallest and the shortest gymnast in 2000 was 28.1 cm; in 2015 that difference was 33 cm.

There's almost no difference (p(t-test) > 0.05) in gymnasts' body weight between the years. In 15 years of difference the gymnasts tend to be heavier on pommel horse, rings and parallel bar, and lighter on high bar. There is also a difference between gymnasts for the apparatus they compete on. According to the measurements the lightest gymnasts competed on rings and the heaviest on pommel horse and high bar (despite the tendency of being lighter after 15 years on that apparatus). Among all the measured gymnasts the lightest was only 49.8 kg (in 2015) and the heaviest gymnast 84.5 kg (in 2000). They were both competing on a high bar. And with the exception of a high bar this doesn't reinforce the idea that gymnasts are getting shorter and lighter, mentioned by Arkaev & Suchilin (2003).

BMI shows no significant difference (p(t-test) > 0.05), which is assumed according to the results for height and weight, although the gymnasts tend to have a lower BMI in 2015 than in 2000. The gymnasts tend to be taller and not so much heavier in 15 years of difference. By Arkaev & Suchilin (2003) the gymnast's weight is the only objective obstacle to perform exercises. To move one's weight it's necessary to apply strength and perform mechanical work of a certain power. So the gymnasts have to try to keep a certain body weight, despite the tendency to be heavier.

In measurements for circumferences there's no significant difference (p(t-test) > 0.05) in arms circumference, there's also no difference between left and right arm. The difference is significant in abdomen circumference (p(t-test) < 0.05) for all the apparatus except for rings. The average difference on the apparatus (except for rings) between the years is from 2.5 to 4.4 cm. We can confirm that in 15 years gymnasts tend to have greater abdomen circumferences.

As Arkaev & Suchilin (2003) said gymnastics cannot be performed without jumping ability, high level of development of the muscles of upper back, lower back and the trunk. The trunk is amazing in construction and a very important tool for mastering the technique of performing modern gymnastics exercises. This obviously was the leading point of perspective for gymnasts and their coaches, to pay more attention to development of the trunk muscles than they were in the past. Consequently the abdomen circumferences are greater in 2015 that they were in 2000. Here, the similarity in measurement techniques must be mentioned. Measurements in 2000 were performed with standard anthropometrical instruments (measuring tape), measurements in 2015 were taken with the InBody720. The procedure of measurements remained the same; in both techniques the circumference was measured in the navel line, so we can neglect the measurement error.

Comparing the percentage of gymnasts' body fat mass there's no significant difference (p(t-test) > 0.05) between the years. The fat mass percentages of the gymnasts in this study are low comparing to the general population, which once again confirms the findings and data published by other authors (Johnston & Padez (2009), Faria I.E. & Faria E.W. (1989), Caldarone et.al (1987)). Nevertheless gymnasts tend to have lower values of percentage of body fat mass in 2015, comparing to 2000.

The percentage of muscle mass shows a significant difference (p(t-test) < 0.05) on each apparatus, except for rings. On rings the relative strength of the body has a

significant meaning, where additional body mass does not necessarily represents higher absolute power. The highest difference is in percentage of muscle mass of gymnasts competing on floor, and it is the only difference that shows gymnasts had more percentage of muscle mass in 2015 than in 2000. On the other three apparatus – pommel horse, parallel and high bar, the significant difference shows the gymnasts had had more percentage of muscle mass in 2000 than they had in 2015.

There is three times that F-test was significant (F > p(F-test)). In BMI on parallel bars, percentage of body fat mass on pommel horse and percentage of muscle mass on floor. Among those, the significant difference between the years (p(t-test) < 0.05) is only in percentage of muscle mass on floor, the other compared variables are not significantly different, but there is a big difference in variance between these variables in 15 years. And in almost 80% of all compared variables for the apparatus, the level of variance in variables in 2015 was much bigger than it had been in 2000. Even if there are no significant difference in measured (or calculated) values, there is a tendency for bigger differences between the lowest and the highest value of different variables, which means the change of rules, structural change of routines, different deduction procedure and increasing number of specialists on different apparatus did have some affect to morphological characteristics of gymnasts.

We don't have data for bone density, but it would be interesting to compare values of it between the years. According to the changing of bone mass density and skeletal status with trainings in artistic gymnastics (as stated in Nichols-Richardson, et. al, 2000; Dowthwaite & Scerpella, 2009; Nichols et al. 1994; Pullock, et. al, 2006; and many others), values of bone density might also change with years. As our results show, gymnasts in 2015 tend to have lower percentage of body fat, lower percentage of muscle mass and almost unchanged body weight, we assume the difference comes from higher percentage of bone mass and higher mass of inner organs. Comparing the floor routines from different years on videos, gymnasts in 2000 mostly had 3 diagonals, each with mostly one basic difficult acrobatic element within a diagonal, but gymnasts nowadays mostly have 4 diagonals of difficult acrobatic elements, also with two difficulties within a diagonal. A quantitative increase of body loan in take offs and landings of difficult acrobatic elements might also lead to an increase of percentage of bone mass. So further research is necessary to compare bone density, there might also be interesting to verify some potential changes in insertion according to the execution of higher difficulty level nowadays.

EXPERIMENT LIMITATIONS

Differences in measurement techniques limited the comparable morphological characteristics. Due to that we could not compare chest circumference, thigh circumference and skeletal lean mass. We don't know how the InBody720 calculating procedure for percentage of muscle mass and percentage of fat mass, but they were still compared to see the difference. Gymnasts competing on vault were not compared because of the lack of data.

For further analysis the same measurement techniques have to be used and compared to get more reliable results.

FIG, or UEG and other continental federations might consider integrating and connecting the researchers from different countries and organizations, to get the data and variables from all the World Cup competitions in different locations, to conduct researches and update of database for further analysis. InBody720 is inexpensive and fast method for determination of morphological

characteristics and can be used in competitions.

CONCLUSION

Comparing the results of anthropometrical measurements of male gymnasts from different years gave some significant and some insignificant differences. In short we can conclude:

- There was a significant change of rules and the COP in 15 years;
- Gymnasts show elements and routines with increased difficulty;
- Gymnasts nowadays show the increase of variability in morphologic characteristics;
- Gymnasts nowadays have higher abdomen circumferences,
- Gymnasts nowadays who compete on floor have higher percentage of muscle mass; while on other apparatus the percentage of muscle mass is lower,
- Gymnasts nowadays tend to be higher, with less percentage of body fat and percentage of muscle mass (with the exception of gymnasts competing on floor).
- nowadays gymnasts with lower percentage of body fat, lower percentage of muscle mass and almost unchanged body weight have probably higher percentage of bone mass and higher mass of inner organs.

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SHORT HISTORICAL NOTES IX

Anton Gajdoš, Bratislava, Slovakia

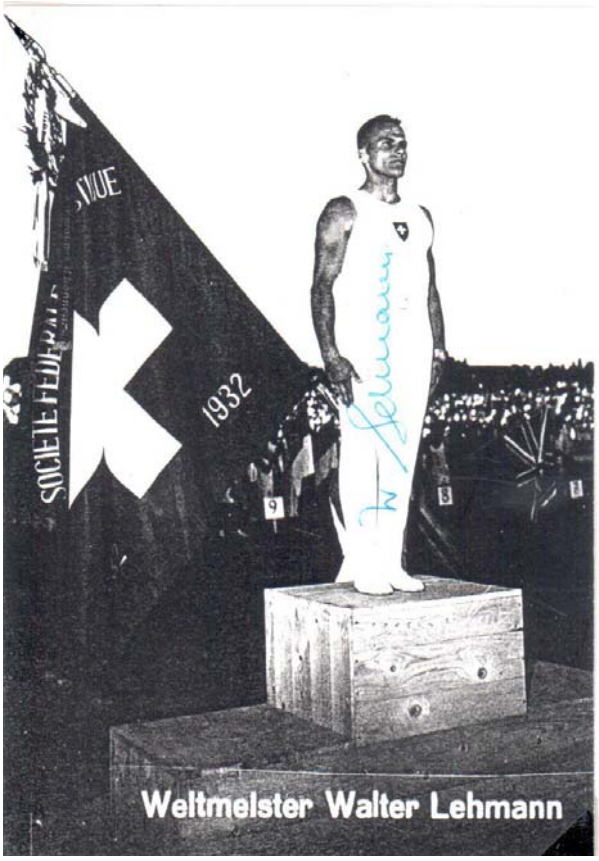
Ph.D. Anton Gajdoš born on 1.6.1940 in Dubriniči (today Ukraine) lives most of his life in Bratislava (ex TCH, nowadays SVK). He comes from gymnastics family (his brother Pavel have world championship medals) and he devoted his life to gymnastics. His last achievement is establishment of Narodna encyklopedia 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.

GERMAN TEAM AT OG 1896

Standing from left: Gustav Felix Flatow, Fritz Hofmann, Gustav Schuft, sitting on fence: Richard Rostel, Conrad Bocker, Hermann Weingärten, Alfred Flatow, Richard Gadebusch, sitting on floor: Fritz Mantenffel, Carl Schuhmann.

Team Olympic Champions on parallel bars and horizontal bar and individual Olympic Champions: Wingärtner Hermann on horizontal bar, Alfred Flatow on parallel bars, Carl Schuhmann on vault.

WALTHER LEHMAN (13.11.1919, Richterswil Swiss)



Momentraly the oldest living gymnast with Olympic medal and title of World Champion in all around.

His the first important international competition were Olympic Games in London in 1948. In London he took 3 silvers, for all around, horizontal bar and as a team member.

Walter was even more successful at World Championship in Basel in 1950, where he earned 3 gold medals (all around, rings and team) and 3 bronze medals (pommel horse, vault and horizontal bar).

After finishing his career as a gymnast, he continued to work in gymnastics. He was excellent international judge, for what in 1972 earned title of the World's Best Judge. In 1984 he retired from all gymnastics duites.

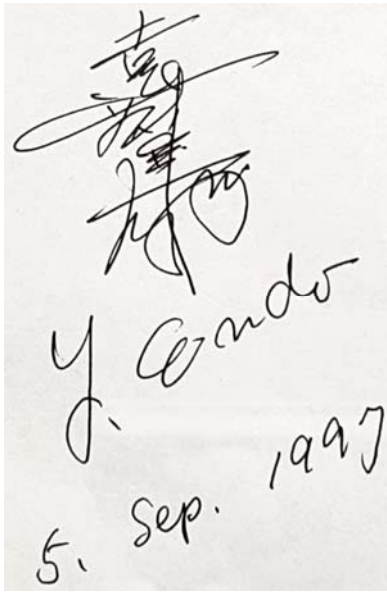
YUKIO ENDO (18.1.1937, Akita, Japan – 25.3.2009, Tokyo)

Yukio Endo competed in time, when Japanese gymnastics dominated world and he won 3 consecutive team titles at Olympic Games 1960, 1964 and 1968. At OG in Tokyo he also won all around title and parallel bars title, silver medal on floor, his collection of Olympic medals supplemented silver on vault at OG 1968 in New Mexico. Photo is from 1964 OG, where he dominated the gymnastics world.

Yukio attended two World Championships (1962, Prague and 1966, Dortmund). With his team, he won two titles. As individual he won on floor and placed second in all around, rings, horizontal bar and third on parallel bars in 1962. In 1966 he took two silver medals for floor exercise and horizontal bar.

His name is daily in gymnastics halls and at all competitons as he gave name to element on high bar which can be described as free circle forward with straddled or legs together through handstand. Draw of his element is from FIG Code of Points (2017).

After retirement from being gymnast, he was coach (national coach at OG 1972, where Japan won), professor at Nihon University, director of Japanese Olympic Committee and vice president of Japanese Gymnastics Federation (two mandates).



Slovenski izvlečki / Slovene Abstracts

Thomas Heinen, Anja Brinker, Melanie Mack in Linda Hennig

VLOGA POLOŽAJA TOČK OKOLJA PRI NADZORU IZVEDBE PRESKOKA JURČENKO

Številne prvine pri telovadbi zahtevajo natančno vzajemno delovanje med telovadcem in okoljem. Nejasno ostaja, kako različne točke v okolju učinkujejo in delujejo pri nadzoru zapletenih prvin, kot so Jurčenko preskoki, kjer telovadec opravi premet vstran z obratom nazaj kot naskok na odrivno desko. Namen te študije je bil oceniti vloge obeh objektov, položaj blazine pred odrivno desko in položaja odskočne deske, pri nadzoru časovnih spremenljivk pri Jurčenku. Kinematični parametri osmih telovadk so bili izmerjeni pri običajni izvedbi in dveh poskusnih pogojih z različnimi oddaljenostmi blazine pred odrivno desko in odrivne deske. Rezultati so pokazali, da je bil vidni nadzor nad blazino pri zaletu v povprečju dva koraka pred blazino. Postavitvi dlani na blazino je sledil časovno konstanten let na odrivno desko. Telovadke so v povprečju postavile svoje noge na isto mesto na odrivni deski, ne glede na to, ali je bil položaj odrivne deske spremenjen. Postavitev dlani na kup blazin (namesto mize za preskok) se je spreminjalo v odvisnosti od položaja odrivne deske in dolžine leta do opore na rokah. Ta študija dokazuje, da položaj odrivne deske določa Jurčenka. Znanje o odnosih med informacijskimi viri v okolju in posledično gibalno obnašanje pri telovadbi lahko vaditeljem pomagajo pri razvijanju programov usposabljanja, katerih namen je povečati sposobnosti telovadcev, da te informacije uporabijo pri prvinah in v spreminjajočih se okoljskih razmerah pri vadbi in tekmovanju.

Ključne besede: vidno zaznavanje, zahteve naloge, zaznavanje časa pri Jurčenku, kinematična analiza.

Boštjan Jakše, Barbara Jakše

MOŽNE KORISTI UŽIVANJA OMEGA 3 MAŠČOBNIH KISLIN PRI ORODNI TELOVADBI

Za učinkovito vsakodnevno vadbo telovadcev je pomembno imeti dovolj energetsko in raznovrstno prehrano, ki omogoča pravilno ravnovesje med vzdrževanjem ustrezne telesne sestave, odlične telesne priprave in splošnega zdravja . Kombinacija vnosa pomanjkanja hranil in povečanega obsega vadbe, ki omogoča nadzorovanje telesne mase, ima lahko negativne posledice za prehransko neustreznost, kar lahko vodi ne le do oslabljenega imunskega sistema, temveč tudi nezadostnega okrevanje po vadbi. Danes telovadci uživajo različne prehranske dodatke za izboljšanje telesnih in umskih sposobnosti, za učinkovitejšo ozdravitev, močnejši imunski sistem in lažji nadzor ustrezne telesne mase. Zadostna količina omega-3 maščobnih kislin - tako kot velja za vitamina B12 in D - je običajno del prehrambenih navad in potreb, ki jih lahko izpolnijo z običajno prehrano ali s prehranskimi dodatki. Namen tega članka je sorazmerno jasno oceniti znanstvene dokaze o možnih koristih uživanja maščobnih kislin omega-3 (ALA, EPA in DHA) za različne cilje telovadcev in na koncu kritično povzemati razumna priporočila. Poleg tega je ta članek namenjen spodbujanju raziskovalcev k preučevanju neposrednega vpliva prehrane in potencialno koristnih in dovoljenih prehranskih dopolnil za različne cilje telovadcev.

Ključne besede: telesna masa, gibalne sposobnost, kognitivne sposobnosti.

Sunčica Delaš Kalinski

VRHUNSKE ORODNE TELOVADKE NA DVOJIH OLIMPIJSKIH IGRAH-KAKOVOST ALI SREČA?

Relativno majhno število telovadk sodeluje na olimpijskih igrah in še manjšo število sodeluje na olimpijskih igrah zaporedoma zaradi številnih različnih razlogov. Zato je namen te raziskave: 1) določiti število telovadk, ki so sodelovali na tekmovanju C-I na olimpijskih igrah v letu 2012 in na olimpijskih igrah, ki so potekale leta 2016; 2) določiti značilnosti in razlike v rezultatih zaporednih udeleženk na teh dveh olimpijskih igrah; 3) določiti razlike med zaporednimi udeleženkami in drugimi tekmovalkami na prej določenih tekmovanjih. Ugotovljeno je bilo, da je le 25 telovadk sodelovalo na dveh zaporednih olimpijskih igrah. Od enih do drugih olimpijskih iger so telovadke številčno povečali vse rezultate; znatno povečala rezultat izvedbe in končnih rezultatov na dvovišinski bradlji; znatno znižale rezultat izvedbo in končni rezultat na gredi. V primerjavi z drugimi telovadkami z olimpijskih iger 2012 in 2016 so zaporedne udeleženke imele številčno višje vrednosti v vseh spremenljivkah, vendar so le nekateri izmed njih opredeljeni kot bistveno drugačni. Zaporedne udeleženke so potrdili možnost neprestanega kakovostnega razvoja spretnosti sredi 20-ih let starosti.

Ključne besede: zaporedne udeleženke, tekmovanje C-I, olimpijske igre 2012-2016, ANOVA

Maria Kritikou, Olyvia Donti, Gregory C. Bogdanis, Anastasia Donti, Kalliopi Theodorakou

POVEZANOSTI MED OCENAMI ZA UMETNIŠKI VTIS PRI

Raziskava je preučevala povezanost med gibalnimi sposobnostmi, telesnimi značilnostmi in rezultati umetniškega vtisa pri grških ritmičarkah. Šestinštirideset ritmičark (starih 9,9 ± 1,3 let) je bilo izmerjenih z vrsto spremenljivk telesne pripravljenosti (ravnotežje, gibljivost, moč in vzdržljivost, hitrosti teka z visoko intenzivnostjo) ter spremenljivkami telesnih značilnosti (sestava telesa in somatotip). Ocena uspešnosti za umetniški vtis in njegovih poddelov (enotnost, glasba in gibanje ter izraznost) so bili pridobljeni med obvezno sestavo brez orodja. Večkratne regresijske analize so pokazale, da sta višina odnoženja in hitrost teka z visoko intenzivnostjo pojasnili 43,7% ($p < 0,01$) variance umetniškega vtisa. Prav tako obe prej omenjeni spremenljivki pojasnjujeta 47,1% ($p < 0,01$) in 53,2% ($p < 0,01$) variance v rezultatih poddelov umetniškega vtisa, enotnosti in glasbe ter gibanja. Mišična vzdržljivost iztegovalk hrbta in podkožne gube lopatice sta pojasnjevali 29,2% ($p < 0,01$) variance izraznosti. Ektomorfna značilnost je glavna telesna značilnost somatotipa ritmičark (2,7-3,0-4,2, za endomorfijo, mezomorfijo in ektomorfijo). Rezultati te študije kažejo na pomembnost gibljivosti kolka, zmogljivosti teka z visoko intenzivnostjo, mišične vzdržljivosti iztegovalk hrbta in posebnih telesnih značiulnosti, ki prispevajo k rezultatu umetniškega vtisa pri mladih ritmičarkah.

Ključne besede: izraz, gibalne sposobnosti, obseg gibanja, somatotip, hitrost teka.

Amanda Batista, Rui Garganta, Lurdes Ávila-Carvalho

PLESNI KORAKI, DINAMIČNE PRVINE Z OBRATI IN METI TER MOJSTRSTVA V RITMIČNIH SESTAVAH

Analiza posameznih sestav vrhunskih ritmičark omogoča vpogled v strukturo sestav. Cilj raziskave je bil ugotoviti razširjenost težavnosti (plesni koraki, mojstrstva in dinamične prvine z obrati in meti) pri vrhunskih ritmičarkah, ki so tekmovale v letu 2013 in 2014 na Svetovnem pokalu v ritmiki v Lizboni, v treh katgorijah uspešnosti. Na osnovi 288 obrazcev težavnosti 4 orodij je bila narejena analiza. Sestave so bile razvrščene v tri skupine glede na rang na tekmovanju. Neparametrična testa Kruskal-Walis in Mann-Whitney sta bila uporabljena za ocen razlik med skupinami. Pearsonov korelacijski koeficient je bil uporabljen za ugatavljanje povezanosti med stopnjo težavnosti in končno oceno. Najboljše ritmičarke so prikazale sestave z nekaterimi drugačnimi značilnostmi, čeprav smo zaznali visoko podobnost v težavnosti v sestavah, ki lahko spreminjajo originalnost in raznolikost tega športa. Višja končna ocena ima višjo težavnost, manjše število povezav in mojsterstev, višje število prvin neosonovnih in nižje število prvin osnovnih skupin prvin in mojsterstev. Na drugi strani, višje število mojsterstev in višje število prvin z obrati in dinamičnih prvin z obrati in meti pomeni nižjo končno oceno. Verjamemo, da je so prave razlike v kategorijah uspešnosti opravičene z ocenjevanjem sodnikov težavnosti v obrazcu težavnosti in izvedbi.

Ključne besede: prvine težavnosti, sestave, posameznice, vrhunske ritmičarke.

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RAZLIKE V SPOLU MED ČLANSTVOM PORTUGLASKE TELOVADNE ZVEZE MED LETI 2012 IN 2016

Stopnja odvisnosti za sodelovanje v posameznem športu je odvisna od različnih dejavnikov, kot so dostopnost športa in stereotipi povezani z njim. Telovadba je prepoznana kot šport zgodnje usmeritve, ki jo predvsem določa višje število žensk, kot moških in potrebno je poudariti da je narejeno bistveno manj študij na telovadkah, kot telovadcih. Cilj študije je bilo ugotoviti kakšno je sodelovanje moških in žensk znotraj Portugalske telovadne zveze glede na športne discipline. Pregledani so bili podatki za tekmovalna leta 2012/2013, 2013/2014, 2014/2015 in 2015/2016. Od 14.742 oseb, jih je bilo 81,3% in samo 18,7% moških ($p<0,01$) v letih 2012/2013. Tudi v naslednjih letih je bilo podobno 83,3:16,7 v letu 2013/2014, 84,8:15,1 v letu 2014/2015 in 85,3:14,7 v letu 2015/2016. Značilne razlike so bile v vseh telovadnih športih. Razlik ni bilo v ritmiki, moški orodni in ženski orodni telovadbi, ker so to izključno enospolni športi. Telovadba mora popraviti sodelovanje obeh spolov in izenačevati neenakosti med spoloma.

Ključne besede: telovadba, spol, sodelovanje, športniki, športi.

Karmen Šibanc, Miriam Kalichová, Petr Hedbávný, Ivan Čuk, Maja Bučar Pajek

PRIMERJAVA TELESNIH ZNAČILNOSTI VRHUNSKIH TELOVADCEV MED LOTOMA 2000 IN 2015

V preteklih letih se je tekmovalna orodna telovadba močno spremenila, težavnost sestav se povečuje, tehnologija in oprema se razvijajo, Pravilnik za ocenjevanje se spreminja. V zadnjih 15 letih je Pravilnik za ocenjevanje močno spremenil. Meritve telesnih značilnosti vrhunskih telovadcev leta 200 in leta 2015 v času tekmovanja za Svetovni pokal v Ljubljani so pokazale naslednje značilne spremembe: povečal se je obseg trupa in spremenil odstotek mišične mase. Čeprav ni bilo ostalih značilnih razlik med obema skupinama telovadcev, lahko zaznamo naslednje tendence: povečana telesna višina, manjši odstotek maščobne mase in mišične mase (z izjemo telovadcev na parterju). Z manjšim odstotkom maščobne mase in odstotkom mišične mase ob skoraj nespremenjeni masi telesa, se je verjetno povečal odstotek kostne mase in tudi masa notranjih organov.

Ključne besede: telovadci, orodna telovadba, Pravila za ocenjevanje, telesne značilnosti.