# ANALYSIS OF THE QUANTITY AND QUALITY PARAMETERS IN THE HIGH BAR COMPETITIVE ROUTINES

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***Abstract.*** *This study is intended to highlight the differences between the indicators of the quantity and quality parameters in the evaluation of high bar competitive routines. Eight gymnasts, high bar finalists at the Men's Artistic Gymnastics National Championships, were recorded by a video camera located perpendicular to the plane of motion and were analysed in relation to the judges' score. The indicators of the quantity parameters (difficulty of elements) and quality parameters (specific penalties for technical execution), consistent with their biomechanical characteristics, were established on the basis of the biomechanical video analysis using the Physics ToolKit program, according to the specific requirements for this apparatus (FIG, 2017). The Pearson correlation coefficient was used to identify the relationship between quality and quality parameters in high bar routines, and the parametric Paired t-test for mean difference was used to compare the indicators. The study reveals the difficulty value of the routines and analyses the indicators of the biomechanical characteristics according to the penalties for execution and the judges' score. Strong and moderate connections, but also significant differences between the indicators of the quantity and quality parameters in the high bar routines are also highlighted. In conclusion, it can be confirmed that an optimal relationship between the quality and quality parameters in the high bar routines helps to obtain additional information necessary for the improvement of gymnasts' level of training according to the judges' score and the analysed indicators of the biomechanical characteristics.*

***Keywords:*** *gymnastics, biomechanical indicators, difficulty value, specific penalties for execution, performance.*

## Introduction

Modern artistic gymnastics develops in accordance with the laws and trends of the performance sports from all over the world. The main trends specific to men's artistic gymnastics are the following ones: increasing difficulty of the competitive routines on apparatus, improvement of the execution quality, extension of the geographical development of the artistic gymnastics worldwide, and increase of the number of countries that have not shown interest in this regard until now (Arkaev & Suchilin, 2004).

At international level, men's artistic gymnastics has a very high level of training in both team and individual competitions. However, the sports competition of the national teams revealed a number of problems of the sports training, including: insufficient basic and special technical training, large volume of the workouts in the initial and basic stages of training, with intensification (forcing) for the sports result.

Aiming at the qualification for the 2020 Olympic Games, each team tends to focus on a very good but not necessarily difficult execution, with the exception of some athletes who struggle for increased difficulty in order to win medals.

A contemporary horizontal bar exercise must be a dynamic presentation that consists entirely of the fluid connection of swinging, turning, and flight elements alternating between elements performed near to and far from the bar in a variety of hand grips so as to demonstrate the full potential of the apparatus (FIG, 2017).

The high bar is the most evaluated apparatus of all the events of men's artistic gymnastics sexathlon in terms of technique, variety and difficulty of the content. In this regard, the technique of many elements used on high bar has been transferred to or assimilated with the execution of certain swing movements on other apparatus too, such as still rings, parallel bars and uneven parallel bars. These elements have a special technique in which forces play a decisive role in the execution of all movements. Knowing and understanding the effects of these forces and laws of biomechanics help to understand the technique of the routines and are the basis of their training methodology (Vieru, 1997; Gaverdovskij, 2014).

The Romanian national team had unexpected results in the 2018 and 2019 European Championships and the 2018 World Championships because of the health problems and failure to achieve the performance objectives. So, in order to achieve the intended performance, we considered that some athletes needed higher difficulty of the exercises per group of elements and improved technical execution on apparatus. In this regard, the analysis of the results achieved in competitions show that the apparatus with the lowest score for difficulty and execution is the

high bar. Therefore, to increase the chances of winning the desired medals, the problems that entail the failure to achieve the training objectives must be identified and studied and the modern training technologies must be used.

*The main purpose of this paper* is to show the differences between the indicators of the quantity and quality parameters in the evaluation of the competitive routines on high bar.

*Hypothesis of the paper*. The computerised video analysis of the high bar competition routines, according to the technical requirements per group of elements and the specific penalties for execution, will highlight if there are differences between the studied indicators and will provide supplementary information necessary for the improvement of athletes' level of training.

## Material and Methods

*Participants*

The study monitored eight gymnasts of national and international level (7 of them, members of the national team), with ages between 18 and 30 years, high bar finalists at the Men's Artistic Gymnastics National Championships, Ploiești 2018. The subjects were informed about the test requirements and conditions, and gave their consent to take part in the study.

*Instruments and procedure*

The research was based on the video analysis of the high bar routines captured with the help of a JVC GZ-E105BEU, Full HD, HDMI Output video camera placed perpendicular to the plane of motion. Depending on the content and construction of the routines and on the technical requirements per element group (EG), the routines were divided into parts, and the difficulty value of the elements was identified using the Pinnacle studio program.

Based on the video analysis and the specific requirements for this apparatus (FIG, 2017), the indicators of the quantity parameters were determined in terms of Difficulty score (D): EG I – Long hang swings and turns, EG II – Flight elements, EG III - In bar and Adler elements plus EG IV – Dismounts and the Difficulty Value of the elements (DV): A (0.1), B (0.2), C (0.3), D (0.4), E (0.5), F (0.6), G (0.7) and H (0.8). The indicators of the quality parameters were determined regarding the Execution score (E): deductions for aesthetic and execution errors and deductions for technical errors (points): small - 0.1 pt., medium - 0.3 pt., large - 0.5 pt. and fall - 1.0 pt.

A case study was conducted (subject: B.C., national champion on this apparatus) with biomechanical video analysis by means of the Physics ToolKit program using the postural landmark method for the identification, measurement and evaluation of key elements of the sports technique in the dismount with Double salto backward tucked with 2/1 turn (720º), difficulty value D (0.4).

Also, the Kinovea program was used in our research in order to specify and analyse the penalties for informational purposes only.

*Statistical analysis*

The statistical analysis was made by means of the KyPlot and Microsoft Excel programs and concerned the indicators of the D-score quantity parameters and E-score quality parameters: sum (Σ) of element difficulty per element group, number of executed elements (N), number of athletes (n) and weight of the sum of the number of elements and athletes (Σ N, n (%)). The descriptive calculation of the video analysis indicators and the results obtained in the high bar event (mean, standard deviation - SD) were analysed. The relationship between the indicators of the quantity and quality parameters in the routines on high bar was analysed using the parametric method (Pearson correlation coefficient).

## Results and Discussion

The research results highlight the analysis of the indicators of the quantity and quality parameters for the performances achieved at the Men's Artistic Gymnastics National Championships – the apparatus final. Compared to the first day of the all-around competition, the athletes' performance was lower by -0.1 points at D-score, -0.237 points at E-score and -0.337 points at Final score.

The results for the indicators of the quantity parameters on high bar in terms of sum (Σ) of element difficulty per element group, number of executed elements (N), number of athletes (n) and weight of the sum of the number of elements and athletes (Σ N, n (%)) are shown in Table 1.

Table 1. *Analysis of the indicators of the quantity parameters on high bar according to element groups (n = 8)*

| EG | Indicators | Difficulty values | | | | |
|---|---|---|---|---|---|---|
| | | A (0.1) | B (0.2) | C (0.3) | D (0.4) | E (0.5) |
| I | Sum (points) | 1.0 | 1.8 | 0.6 | | |
| | N | 10 | 9 | 2 | | |
| | N | 6 | 6 | 2 | | |
| | Σ N, n (%) | 44.27 | 43.75 | 11.98 | | |
| II | Sum (points) | | | 1.5 | 4.4 | 0.5 |
| | N | | | 5 | 11 | 1 |
| | N | | | 5 | 6 | 1 |
| | Σ N, n (%) | | | 32.47 | 60.47 | 7.06 |
| III | Sum (points) | | 3.40 | 3.30 | 1.20 | |
| | N | | 17 | 11 | 3 | |
| | N | | 8 | 7 | 3 | |
| | Σ N, n (%) | | 49.91 | 36.48 | 13.61 | |
| IV | Sum (points) | | | 0.90 | 1.20 | 1.00 |
| | N | | | 3 | 3 | 2 |
| | N | | | 3 | 3 | 2 |
| | Σ N, n (%) | | | 36.13 | 37.69 | 26.18 |

Note: Sum (Σ) – sum of executed elements; EG – Element Group, N – number of executed elements, n – number of athletes; Σ N, n (%) – weight from the total EG

The results of the statistical-mathematical calculations show the following aspects: in element group I (EG I) - Long hang swings and turns, at difficulty elements A (0.1 pt.) 10 elements executed by 6 athletes, Sum of 1.0 points with a weight of 44.27% from EG I; at difficulty elements B (0.2 pt.) 9 elements executed by 6 athletes, Sum of 1.80 points with a weight of 43.75% from EG I and at difficulty elements C (0.3 pt.) 2 elements executed by 2 athletes, Sum of 0.60 points with a weight of 11.98% from EG I; in EG II - Flight elements at difficulty elements C (0.3 pt.) 5 elements executed by 5 athletes, Sum of 1.50 points with a weight of 32.47% from EG II; at difficulty elements D (0.4 pt.) 11 elements executed by 6 athletes, Sum of 4.4 points with a weight of 60.47% from EG II; at difficulty elements E (0.5 pt.) 1 element executed by 1 athlete, Sum of 0.50 points with a weight of 7.06% from EG II; in EG III - In bar and Adler elements at difficulty elements B (0.2 pt.) 17 elements executed by 8 athletes, Sum of 3.4 points with a weight of 49.91% from EG III; at difficulty elements C (0.3 pt.) 11 elements executed by 7 athletes, Sum of 3.30 points with a weight of 36.48% from EG III; at difficulty elements D (0.4 pt.) 3 elements executed by 3 athletes, Sum of 1.20 points with a weight of 13.61% from EG III; in EG IV - Dismounts at difficulty elements C (0.3 pt.) 3 elements executed by 3 athletes, Sum of 0.90 points with a weight of 36.13% from EG IV; at difficulty elements D (0.4 pt.) 3 elements executed by 3 athletes, Sum of 1.20 points with a weight of 37.69% from EG IV; at difficulty elements E (0.5 pt.) 2 elements executed by 2 athletes, Sum of 1.00 points with a weight of 26.18% from EG IV.

The results for the indicators of the quality parameters indicators on high bar in terms of sum (Σ) of element difficulty per element group, number of executed elements (N), number of athletes (n) and weight of the sum of the number of elements and athletes (Σ N, n (%)) are shown in Table 2.

Table 2. *Analysis of the indicators of the quality parameters on high bar according to element groups (n = 8)*

| EG | Indicators | Deductions (points) | | | |
|---|---|---|---|---|---|
| | | -0.1 | -0.3 | -0.5 | -1.0 |
| I | Sum | -1.0 | -3.3 | | |
| | N | 10 | 11 | | |
| | N | 7 | 7 | | |
| | Σ N, n (%) | 45.8 | 54.2 | | |
| II | Sum | -0.7 | -1.8 | -1.5 | -1.0 |
| | N | 7 | 6 | 3 | 1 |
| | N | 6 | 5 | 3 | 1 |
| | Σ N, n (%) | 37.03 | 34.59 | 20.27 | 8.11 |
| III | Sum | -0.8 | -5.7 | -1.0 | |

| | | | | | |
|---|---|---|---|---|---|
| | N | 8 | 19 | 2 | |
| | N | 6 | 8 | 6 | |
| | Σ N, n (%) | 26.19 | 57.88 | 15.93 | |
| IV | Sum | -0.2 | -1.5 | -1.0 | -1.0 |
| | N | 2 | 5 | 2 | 1 |
| | N | 2 | 5 | 2 | 1 |
| | Σ N, n (%) | 17.72 | 48.52 | 21.1 | 12.66 |

Note: Sum (Σ) – sum of executed elements; EG – Element Group, N – number of executed elements, n – number of athletes; Σ N, n (%) – weight from the total EG

The results of the statistical-mathematical calculations highlight the following aspects: in element group I (EG I) - Long hang swings and turns at Deductions (points) (-0.1 pt.) from 10 elements executed by 7 athletes, the Sum is -1.00 points with a weight of 44.8% from EG I; at Deductions (-0.3 pt.) from 11 elements executed by 7 athletes, the Sum is -3.3 points with a weight of 54.2% from EG I; in EG II - Flight elements at Deductions (-0.1 pt.) from 7 elements executed by 6 athletes, the Sum is -0.7 points with a weight of 37.03% from EG II; at Deductions (-0.3 pt.) from 6 elements executed by 5 athletes, the Sum is -1.8 points with a weight of 34.59% from EG I; at Deductions (-0.5 pt.) from 3 elements executed by 3 athletes, the Sum is -1.5 points with a weight of 20.27% from EG II; at Deductions (-1.0 pt.) from 1 element executed by 1 athlete, the Sum is -1.0 points with a weight of 8.11% from EG II; in EG III - In bar and Adler elements at Deductions (-0.1 pt.) from 8 elements executed by 6 athletes, the Sum is -0.8 points with a weight of 28.19% from EG III; at Deductions (-0.3 pt.) from 19 elements executed by 8 athletes, the Sum is -5.7 points with a weight of 62.29% from EG III; at Deductions (-0.5 pt.) from 2 elements executed by 2 athletes, the Sum is -1.0 points with a weight of 9.52% from EG II; in EG IV - Dismounts at Deductions (-0.1 pt.) from 2 elements executed by 2 athletes, the Sum is -0.2 points with a weight of 17.72% from EG II; at Deductions (-0.3 pt.) from 5 elements executed by 5 athletes, the Sum is -1.5 points with a weight of 48.52% from EG IV; at Deductions (-0.5 pt.) from 2 elements executed by 2 athletes, the Sum is -1.0 points with a weight of 21.1% from EG IV; at Deductions (-1.0 pt.) from 1 element executed by 1 athlete, the Sum is -1.0 points with a weight of 12.66% from EG IV.

The results of the video analysis indicators and the results obtained in the high bar event regarding the Difficulty score, Deduction, Execution score within the video analysis, Error deduction, Execution score, Final score and Rating score are listed in Table 3.

Table 3. *Results of the video analysis indicators and results obtained in the high bar event (n = 8)*

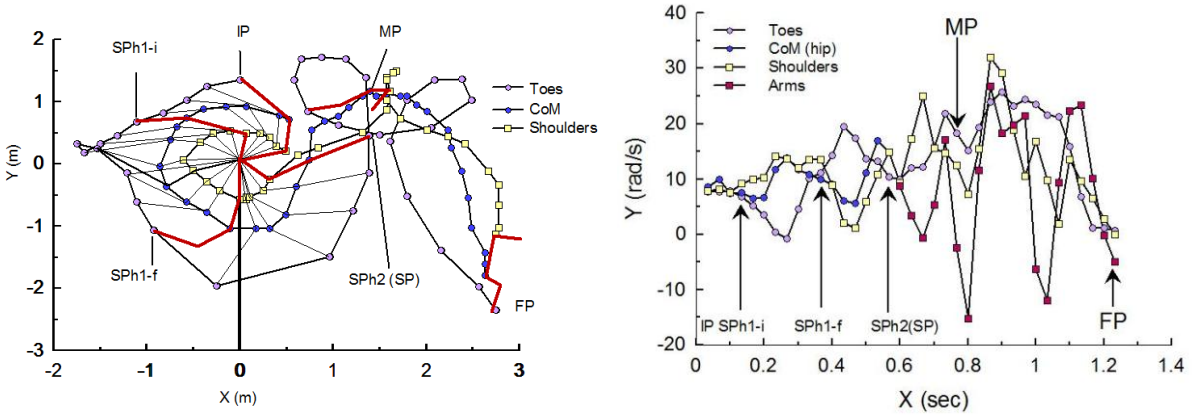
| Item no. | Athletes | D-score (points) | Deduc. (points) | E-score (points) Video analysis | Error deduc. (±) (points) | E-score (points) | Final score (points) | Rating score |
|---|---|---|---|---|---|---|---|---|
| 1 | P.O. | 5.000 | -3.100 | 6.900 | 0.05 | 6.950 | 11.950 | 4 |
| 2 | G.E. | 4.300 | -3.100 | 6.900 | 0.00 | 6.900 | 11.200 | 7 |
| 3 | K.A. | 4.400 | -2.200 | 7.800 | -0.05 | 7.750 | 12.150 | 3 |
| 4 | I.L. | 3.400 | -2.300 | 7.700 | 0.00 | 7.700 | 11.100 | 8 |
| 5 | P.R. | 5.000 | -3.200 | 6.800 | 0.05 | 6.850 | 11.850 | 5 |
| 6 | M.A. | 4.900 | -2.000 | 8.000 | 0.05 | 8.050 | 12.950 | 2 |
| 7 | B.C. | 5.100 | -2.100 | 7.900 | 0.00 | 7.900 | 13.000 | 1 |
| 8 | G.R. | 4.100 | -2.500 | 7.500 | -0.05 | 7.450 | 11.550 | 6 |
| | mean | 4.525 | -2.563 | 7.437 | 0.006 | 7.444 | 11.969 | - |
| | S.D. | 0.59 | 0.49 | 0.49 | 0.49 | 0.48 | 0.72 | - |
| | min | 3.4 | -2.0 | 6.8 | -0.05 | 6.85 | 11.1 | - |
| | max | 5.1 | -3.2 | 8.00 | 0.05 | 8.05 | 13.0 | - |

Note: D – difficulty, Deduc. – deduction, E – execution

The results of the statistical-mathematical calculations reveal the following: the mean and standard deviation (mean; ± SD) of D-score is 4.525; ± 0.59 points, minimum value 3.40 points and maximum value 5.10 points; Deduction value is -2.563; ± 0.49 points, min value -2.0 points and max -3.2 points; E-score within the video analysis is 7.437; ± 0.49 points, min value 6.80 points and max 8.0 points; Error deduction is 0.006; ± 0.49 points, min -0.05 points and max 0.05 points; E-score is 7.444; ± 0.48 points, min value 6.85 and max 8.05 points; Final score is 11.969; ± 0.72 points, min value is 11.10 points and max 13.0 points.

Figure 1 presents the graph of the kinematic characteristics of the dismount by Double salto backward tucked with 2/1 turn (720º), difficulty value D (0.4) on high bar (B.C.), regarding the trajectories of body segments within the phase structure of the sports technique (a) and the angular velocity of body segments in the phase of support on high bar and the flight phase (b).

The biomechanical video analysis was made using the Physics ToolKit program and Pinnacle Studio 14 video capture program. According to the execution technique of the dismounts, the motion was divided into two parts: a) supported rotation of the apparatus, preparatory phase regarding the initial position (IP) – specific to the upper vertical line, SPh 1- i and SPh 1- f (hanged swing), SPh 2 - launching posture before leaving the high bar (LP) and b) Rotation motion without support (flight), basic phase, regarding the multiplication of body posture tucked at the maximum height of CoM (MP); final phase, regarding the concluding posture - landing.




a) Trajectories of body segments b) Angular velocity of body segments

Note: CoM – centre of mass; IP- initial position in handstand, SPh1-i – sub-phase 1 - initial (horizontal shoulders-toes), SPh1-f – sub-phase 1- final (start of hanged swing), SPh2 – sub-phase 2 (launching body posture), MP - multiplication body posture (maximum height of CoM) and FP – final position (concluding posture) – landing

*Figure 1.* Graph of the kinematic characteristics of the dismount by Double salto backward tucked with 2/1 turn (720º), difficulty value D (0.4) on high bar (B.C.)

The following indicators necessary for the analysis were used in the rotation motion on the apparatus: Rotational inertia (RI) = 260.81 kgm$^2$, Radius of the motion (RM): toes – 1.481 m, CoM – 0.912 m shoulders – 0.532 m. in the motion without support (flight phase) RI = 32.748 kgm$^2$ and RM: CoM-toes – 0.748 m, CoM-shoulders – 0.675 m, CoM-knee – 0.382 m and CoM-arms – 0.537 m.

P.I. (t(s) = 0.00 sec) shows the trajectory of body segments in vertical position above the bar, where the shoulders (m) are placed before the vertical at X = 0.449 m; Y = 0.214 m and CoM (m) – X = 0.534 m; Y = 0.712 m while the toes (m) are above the bar vertically at X = 0.000 m; Y = 1.353 m.

The preparatory motion SPh 1 i (t(s) = 0.133 sec) and f (t(s) = 0.367 sec) the motion for preparing the "hanged swing", (i) – starts with the shoulders (m) close to the upper vertical of the bar at X = 0.071 m; Y = 0.499 m, CoM (m) at X = -0.392 m; Y = 0.89 m and toes (m) at -1.104 m; Y = 0.677 m and in (f) – the motion ends with the toes (m) at X = -1.104 m; Y = -0.605 m, CoM (m) at X = -0.356 m; Y = -0.784 m and the shoulders closer to the lower vertical of the bar at X = -0.214 m; Y = -0.427 m.

The preparatory motion, start position (SP), SPh 2 (t(s) = 0.567 sec) highlights the end of the "hanged swing" before releasing the bar with the toes (m) at X = 1.389; Y = 0.463 m (above the bar), CoM (m) at X = 0.748 m; Y = -0.071 m (at bar horizontal) while the shoulders at X = 0.321 m; Y = -0.249 m (under the bar horizontal).

The basic phase of the motion, multiplication of body posture (MP) at (t(s) = 0.233 sec), the second part of the analysis, shows the CoM (m) at X = 1.392 m; Y = 1.172 m (maximum height of the flight) and the shoulders (m) at X = 1.575 m; Y = 1.392 m while the toes (m) at X = 0.732 m; Y = 0.842 m (horizontal position above the bar with shoulders forward).

The concluding phase, final position (FP), landing (t(s) = 0.700 sec) presents the toes (m) at X = 2.746 m (length of the dismount); Y = -2.344 m and shoulders (m) at X = 2.746 m); Y = -1.135 m (correct landing with shoulders on the same line as the soles).

As for the angular velocity of body segments (rad/s) in the case of the dismount by Double salto backward tucked with 2/1 turn (720º), difficulty value D (0.4) on high bar (B.C.), we notice that in the preparatory motion phase in rotation with support on the apparatus, during the "hanged swing" SPh 1 (i) (rad/s) the shoulders have a higher value– 9.126 rad/s, then the CoM – 7.552 rad/s and toes – 6.781 rad/s while at (f) (rad/s) – the values are as follows: shoulders (rad/s) – 13.577 rad/s, toes – 11.206 rad/s and the CoM – 9.879 rad/s, the pelvis remains behind the body line.

In SPh 2, (SP) the movement of ending the "hanged swing" before releasing the bar, there is a slowdown of 10.365 rad/s of the toes (rad.s) and an increase in CoM – 14.816 rad/s and at shoulders – 14.79 rad/s, allowing the release of the bar as efficiently as possible.

The basic phase of the motion, multiplication of body posture (MP) (rad/s) highlights, at the maximum height of CoM horizontally related to the floor, a higher value at toes – 18.261 rad/s, then knees – 17.393 rad/s (ensuring the body rotation in transversal axis), afterwards shoulders – 12.522 rad/s and arms with negative value -2,373 rad/s (rotation in the longitudinal axis of the body).

The final position, (FP) (rad/s) – landing: we notice the smaller value at shoulders – 0.004 rad/s and toes – 0.735 rad/s and the negative value in opposite direction at arms – -5.007 rad/s – making possible to stop the rotation and to stick the landing; the higher value at the knee – 5.59 rad/s – dampening of the landing.

The relationship between the quantity and quality indicators of the routines on high bar was analysed using the parametric method of linear correlation (Pearson correlation coefficient) monitoring the relation of the sum of difficulty values at each element group (EG) and the deduction sum at EG for each athlete.

Table 4. *Correlative analysis between the quantity and quality indicators in the high bar routines*

| R; P-Value | Element group | Quality indicators Element group | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| Quantity indicators, EG | I | .842**; .008 | -.859**; .006 | -.324; .433 | -.486; .222 |
| | II | -.767*; .026 | .645; .084 | -.011; .979 | .315; .445 |
| | III | -.307; .459 | .068; .872 | .731*; .039 | .216; .606 |
| | IV | -.565; .145 | .208; .621 | -.137; .707 | .324; .434 |

Note: ** - $p < 0.01$; * $p < 0.05$

The results of the correlative analysis (Table 4) highlight strong connections at $p < 0.01$ between element groups I (EG) for both the element difficulty (quantity) and their deduction (quality), R = .842; p-value = .008; between EG I (quantity) and EG II (quality) R = -.859; p-value = .006. There are strong connections at $p < 0.05$ between EG II (quantity) with EG I (quality) R = -.767; p-value = .026 and between EG III quantity and quality R = .731; p – value = .039. The other relationships between indicators have moderate and weak connections.

The analysis of the strong connection relationship shows the mutual influence of EG I (Long hang swings and turns) and EG III (In bar and Adler elements) between the quantity and quality indicators and of EG I and EG II (Flight elements), both in terms of difficulty (quantity) and execution – deduction (quality).

Our research on the analysis of the quantity and quality parameters in the high bar competitive routines involved a review of the literature that revealed the existence of scientific approaches regarding the following aspects: concerns with and biomechanical studies on the giant circle on high bar (Hiley, 1998); investigation of the kinematic dynamic structure of dismount giant swings backward executed effectively on horizontal bar and uneven bars (Knoll, 2001); demonstration that the double Jaeger is actually possible to be performed and identification of the mechanical conditions the athlete must fulfil to have the competence to perform (Heinen et al., 2011); explanation of the joint kinetic profiles, identification of the physical demand placed on the performer and final assessment of the similarities with the target skill (Irwin & Kerwin, 2006); analysis of the technical characteristics of the Kolman and Pegan saltos and their comparison with the Kovacs salto and the Gaylord I salto (Čuk, 1995); biomechanical and biological limits in artistic gymnastics (Bruggemann, 2005); usage of visual feedback technologies for performance improvement of men's artistic gymnastics (Puiu, Dragomir, & Bidiugan,

2018); analysis of the HR and BL from one apparatus to another during the six events (Floor, Pommel horse, Rings, Vault, Parallel bars and Horizontal bar) of men's gymnastics competition, examination of the physiological effects of performing a series of gymnastics events (Jemni, Friemel, Lechevalier, & Origas, 2000); predicting the high bar forces in the long swing (Kerwin & Irwin, 2006).

As for the competitive performance analysis, there are studies that focus on problems such as: analysing the results of World Championships, performance scores and standings in the World Artistic Gymnastics Championships; comparative study on the evolution of the high performance results achieved by the Romanian artistic gymnastics men's and women's teams during the last two editions of the World Championships, taking into consideration that this would also identify their preparation stage for the London Olympic Games in 2012 (Atiković, Kalinski, Bijelić, & Vukadinović, 2011; Massidda & Calò, 2012; Dobrescu, 2010); the performance and health concepts in artistic gymnastics (Bradshaw, 2010); qualitative and quantitative analysis of the preparation for high level competitions in artistic gymnastics between 2001 and 2008 in Romania (Stroescu, 2014); how apparatus difficulty scores affect all-around results in men's artistic gymnastics; modelling of the final score in artistic gymnastics by different weights of difficulty and execution (Čuk & Forbes, 2010; Čuk, Fink, & Leskošek, 2012); a pre-performance routine to optimise competitive performance in artistic gymnastics (Gröpel & Beckmann, 2017).

## Conclusion

The research results are based on the analysis of the indicators of the quantity and quality parameters for the performances achieved in the apparatus final at the Men's Artistic Gymnastics National Championships.

The results highlight the analysis of the above indicators for the high bar event in terms of the sum of the difficulty and deductions of elements per element group, the ratio between the number of executed elements and the number of athletes, and also the weight of the sum of the number of elements and athletes per element group.

The results of the video analysis indicators and the results obtained in the high bar event are characterised by equal results at the difficulty score, in accordance with the deduction and execution scores within the video analysis, compared to the execution score, final score and rating score, with errors in deductions of ± 0.05 points (calculated mean).

The biomechanical video analysis presents the graph of the kinematic characteristics of the dismount with double salto backward tucked with 2/1 turn (720º), difficulty value D (0.4) on high bar, regarding the trajectories of the body segments in the phasic structure of the technique and the angular velocity of body segments in the phase of support on the apparatus and the flight phase.

There is a mutual influence of the element groups I and III between the indicators of the quantity and quality parameters and between EG I and EG II, from the standpoint of the difficulty and execution – deduction as well.

The computerised video analysis of the high bar competition routines, according to the technical requirements per group of elements and the specific penalties for execution, has revealed significant differences between the studied indicators and has provided supplementary information necessary for the improvement of athletes' level of training, which confirms the proposed hypothesis.

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