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Original Article

A comparative analysis of scores and chronological age of participants in the 2017-2020 Olympic cycle individual Rhythmic Gymnastics Continental Championships

KATARZYNA STERKOWICZ-PRZYBYCIEŃ[1]
[1]Department of Gymnastics and Dance, Institute of Sport Sciences, University of Physical Education in Krakow, POLAND

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Abstract:
Comparing the scores of performances and chronological age in participants of Rhythmic Gymnastics Continental Championships in one Olympic cycle (2017-2020) has the potential to indicate the global differences in the development of this sport. The aim of the study was to, 1) identify the events characterized by the highest/lowest gymnasts' achievements based on judges scores, and determine the differences in total scores, difficulty and execution of all-around, hoop, ball, clubs and ribbon in qualification competition, and finals, across Continental Championships (CC), and 2) compare the chronological age of CC participants. The material was obtained from the official RG Results Books and official documents of five Continental Championships. The total sample included individual rhythmic gymnasts (n=116) that participated in all-around and finals of: 15th African Championships (ACh), Sharm El Sheikh, EGY, (n=15); Oceania RG CC (OCh), Carrara, QLD, AUS, (n=17); 12th Senior Rhythmic Gymnastics Asian Championships (AsCh), Tashkent, UZB, (n=11); 37th European Championships in Rhythmic Gymnastics (ECh), Varna, BUL, (n=52); Rhythmic Gymnastics Senior Pan American Championships (PACh), Rio de Janeiro, BRA, (n=21). For each final (hoop, ball, clubs, ribbon), the eight qualified gymnasts' scores were compared except for OCh where only six gymnasts for each apparatus qualified. The gymnasts' chronological age was also calculated. The Kruskal-Wallis test and a post-hoc Bonferroni test at the 95% confidence level were used. The comparative analysis determined the events that were characterized by the highest or lowest judges' scores and showed significant differences in total, difficulty, and execution scores for hoop, ball, clubs, and ribbon between all-around qualification competitors ($p<0.001$), and between apparatuses finalists ($p<0.001$) across CC participants. The chronological age significantly differentiated participants in all-around competition ($H=12.6$, $p<0.01$, $\eta^2=0.078$) showing gradation from the youngest to the oldest: ACh<OCh<ECh<AsCh<PACh. Moreover, the ball and ribbon ECh finalists were significantly older from those of OCh and ACh finalists ($p<0.001$). The results of the present study may be used in future analysis of scores and chronological age of rhythmic gymnasts representing particular CC to monitor the trend between front rank events' competitors and those with lower achievements. This can be informative for gymnastics federations and state institutions that are able to organizationally and systemically support the sport development.
Key Words: aesthetic sport, elite athletes, evaluation, performance analysis, age characteristics

Introduction

Rhythmic gymnastics (RG) is a female aesthetic sports discipline characterized by acyclic motion structures including body and apparatus technical elements performed in harmony with music accompaniment (Starosta, 2009). In this sport discipline the routines with rope (except for the individual seniors), hoop, ball, clubs, and ribbon are executed by gymnasts on a specific floor area (13m x 13m), either as individuals (in time of 90s) or as a group competition (in time of 2.30s) (FIG, 2018). The wide range of factors determines the success in this complex sport discipline, from gymnasts' thin body constitution (Purenović-Ivanović, Popović, Bubanj, & Stanković, 2016), and optimal level of motor abilities i.e. flexibility, strength, explosive strength, motor coordination, rhythmization, balance (Boligon, Depra, & Rinaldi, 2015; Sterkowicz-Przybycień & Fundament, 2020; Purenović-Ivanović, Popović, Stanković, & Bubanj, 2016;) that influence the performance of technical elements (Donti, Bogdanis, Kritikou, Donti, & Theodorakou, 2016), continues through psychological preparedness (Blumenstein, & Lidor, 2007), to monitored and supported by coach participation in competition, included in well-planned training process (Sterkowicz-Przybycień & Purenović-Ivanović, 2021).

The rules of evaluation of the RG performance's quality are unified in the Code of Points (COP) that specify quantitative criteria such as the number of body and apparatus elements and qualitative criteria such as artistic value or the harmony of the movement with the pace and nature of the background music (FIG, 2018; Hökelmann, Liviotti, & Breitkreutz, 2013). The changes in COP aim to discipline development and amplify judge's objectivity in scoring used to be made by International Gymnastics Federation every four years after the

Corresponding: KATARZYNA STERKOWICZ-PRZYBYCIEŃ, E-mail: katarzyna.sterkowicz@awf.krakow.pl

Olympic Games. This influences the competition routines' compositions concerning the number of technical elements and their relation to final score (Sierra-Palmeiro, Bobo-Arce, Pérez-Ferreirós, & Fernández-Villarino, 2019). The technical value of apparatus difficulty with particular emphasis on Mastery value demonstrated an upward trend in two consecutive World Championships 2013 and 2017 (Leandro, 2018). The 2017-2020 COP eliminated the upper limit of 10 points for Difficulty component and increased the values of technical and artistic faults deductions in comparison to previous COP (Chiriac, 2020). Gymnasts competing according to 2017-2020 COP performed more ballet movements during Apparatus Difficulties and Dynamic Elements of Rotation, and less ballet movements in Dance Step and connections than those who competed according to the 2013-2016 COP (Furtado, De Toledo, Antualpa, & Carbinatto, 2020). The artistic aspects of performance have evolved in COP over the years represents an important component of the final score (Toledo, & Antualpa, 2016).

In official Fédération Internationale de Gymnastique (FIG) competition the sports excellence is assessed by two panels of judges consisting of a difficulty judges' panel (D-panel), four judges divided into two subgroups and an execution judges panel (E-panel), six judges divided into two subgroups with two judges evaluating artistic faults, and four judges evaluating technical faults. Generally, the D-panel is responsible for evaluating the number and technical value of body difficulties which consists of jump/leaps, balances, rotations (the nine highest correctly performed are counted), number and technical value of dance steps combinations, the number and technical value of dynamic elements with rotation (maximum five), the number and technical value of the apparatus difficulty to determine the final difficulty score. There are no score upper limits. The E-panel is responsible for evaluating artistic component and technical faults by deduction. The artistic and technical deductions are subtracted from 10.00 points to determine the final execution score (FIG, 2018).

The literature review shows, RG judging is not free from subjective perception in the evaluation of routines executed by gymnasts, and fraught with bias, such as national bias which refers to judges favoring gymnasts from their country (Popović, 2000; Heiniger, & Mercier, 2018, 2021). The evaluation of the difficulty component in RG routines is more subjective with regard of mastery and dance steps, and less subjective with regard to difficulties of balance. Whereas evaluation of the execution component is most subjective with regard to artistic faults, specifically with the harmony of music and movement (Leandro, Ávila-Carvalho, Sierra-Palmeiro, & Bobo-Arce, 2016a). Some researchers have noted that disagreement between D-panel judges occurred in 40% of the evaluated elements. Furthermore, the level of evaluation accuracy was differentiated according to the level of gymnasts' places in the final ranking as well as decreased in the mastery elements and dynamic elements of rotation (Leandro, Ávila-Carvalho, Sierra-Palmeiro, & Bobo-Arce, 2015). The above determinants of RG judging can hinder the RG performance analysis based on scores (Hökelmann, Liviotti, & Breitkreutz, 2013). Nevertheless, the final score is definitive effect of sports performance that can be compared between gymnasts of different levels of achievements (rankings) or sports events (Sterkowicz, & Sterkowicz, 2005; Sterkowicz-Przybycień, 2004).

Previous publications have examined the scores as the effect of performance in RG in context of departure difficulty score vs final difficulty score (Leandro, Ávila-Carvalho, Sierra-Palmeiro, & Bobo-Arce, 2016b). Other studies have examined the evolution of the average final score and average number of elements for each apparatus over the time of thirteen World Championships taking into account the changes in COP (Sierra-Palmeiro, Bobo-Arce, Pérez-Ferreirós, & Fernández-Villarino, 2019). Some studies were aimed at identifying the most indicative apparatus score on total ranking in the individual all-around finals noting the effect of difficulty and execution scores in World Championships, as well as comparing total scores, difficulty and execution scores in two consecutive European Championships (Örs, 2020, 2021). Another study identified the effect of age on competition total scores and its components in juniors (Tatlibal, Kutlay, & Oral, 2021).

The problem of chronological age in gymnastics was previously analyzed in artistic gymnasts in historical context, suggesting differences between Olympic Games and World Championships medalists (Atiković, Kalinski, & Smajlović, 2017, Atiković, Kalinski, & Čuk, 2017). The comparison of three Olympic Games (1996-2004) participants' age showed that rhythmic gymnasts were significantly older from artistic gymnasts with their average age of 19,33 and 18.18 years old respectively (Sterkowicz-Przybycień, & Omorczyk, 2006). The minimal participants' age limit for all FIG RG 2020 Olympic Games qualification events, including CC, was set at 16 years or older (Directives of ACh, 2020; Directives of OCh, 2021; Directives of AsCh, 2021; Directives of ECh, 2021; Directives of PACh, 2021). RG is an early specialization sport (Ford, & Williams, 2017) and it can be estimated gymnasts 16 years old and above will have 10 years or more of training experience (Sterkowicz-Przybycień, & Fundament, 2020). Researchers suggest at minimum of 10 years or 10,000 hours of practice as the necessary period to achieve the highest level of performance in the given domain (Ericsson, Krampe, & Tesch-Römer, 1993). Wherein, the training volume was significantly higher and increased more on subsequent stages of sport development in Olympic level rhythmic gymnasts compared to those of international level (Law, Côté, & Ericsson, 2007).

An analysis of the literature indicates a lack of evidence comparing scores and chronological age of rhythmic gymnasts competing in CC during the Olympic cycle. Thus, the aim of the present study was to: 1) indicate the events characterized by the highest/lowest gymnasts' achievements based on judges scores, and determine the differences in total scores of all-around, hoop, ball, clubs and ribbon, and the difficulty and execution components of the result in qualification competition and apparatuses finals, as well, across individual

RG CC, and 2) compare the chronological age of CC participants. This information will highlight the strengths and weaknesses of the performance based on total, apparatus, difficulty and execution scores of rhythmic gymnasts to allow for improvement of the results, show the level of performance based on scores and indicate the global differences and similarities in the development of RG globally. Furthermore, comparison of chronological age could give actual characteristics and indicate differences between rhythmic gymnasts representing five continents at senior level.

Material & methods

The data for the study was obtained from the official RG results and official documents available on the FIG website (https://www.gymnastics.sport/site/events/searchresults.php) and/or on the official websites of the respective sport events' organizing committees (http://egypt@egyptgymnastic.com, http://ausgymnasticschamps.com.au/results/, http://www.agu-gymnastics.com/). The total sample of N = 116 individual rhythmic gymnasts' all-around results, finalists' results and dates of birth were composed from five CC: 15th African Championships (ACh), Sharm El Sheikh, EGY,12-16 March, 2020 (n=15); Oceania RG CC (OCh), Carrara, QLD, AUS, 13-16 May, 2021 (n=17); 12th Senior Rhythmic Gymnastics Asian Championships (AsCh), Tashkent, UZB, 8-10 June, 2021 (n=11); 37th European Championships in Rhythmic Gymnastics (ECh), Varna, BUL, 9-13 June, 2021 (n=52); Rhythmic Gymnastics Senior Pan American Championships (PACh), Rio de Janeiro, BRA, 11-13 June, 2021 (n=21). Because of coronavirus pandemic most of 2017-2020 Olympic cycle CC were postponed to 2021.

With regard to apparatus finals, for each final (hoop, ball, clubs, ribbon), eight qualified gymnasts from each individual event (except OCh where only six gymnasts qualified) were compared. Only complete data for all-around qualification competition and apparatus finals were analyzed. In the case of ECh that all-around finals were conducted after the qualification competition, the results of these all-around finals were not taken into analysis in the present study so that to include all of ECh participants that had right to represent their countries in CC (Directives of ECh, 2021).

Ethical considerations

The research was conducted in accordance with the ethical standards of sports science (Harris and Atkinson, 2009). Ethical committee approval was not required to, as only publicly available data was used.

Variables

The judges' scores of All-Around Total Score (AATS), Hoop Total Score (HTS), Ball Total Score – (BTS), Clubs Total Score (CTS), Ribbon Total Score (RTS); Total Difficulty Score (TDS; calculated by summation of particular apparatuses difficulty scores), Hoop Difficulty Score (HDS), Ball Difficulty Score (BDS), Clubs Difficulty Score (CDS), Ribbon Difficulty Score (RDS); Total Execution Score (TES; calculated by summation of particular apparatuses execution scores), Hoop Execution Score (HES), Ball Execution Score (BES), Clubs Execution Score (CES), Ribbon Execution Score (RES); Finalists' Hoop Total Score (FHTS), Finalists' Ball Total Score (FBTS), Finalists' Clubs Total Score (FCTS), Finalists' Ribbon Total Score (FRTS), Finalists' Hoop Difficulty Score (FHDS), Finalists' Ball Difficulty Score (FBDS), Finalists' Clubs Difficulty Score (FCDS), Finalists Ribbon Difficulty Score (FRDS), Finalists' Hoop Execution Score (FHES), Finalists' Ball Execution Score (FBES), Finalists' Clubs Execution Score (FCES), and Finalists' Ribbon Execution Score (FRES). The chronological age was calculated using Microsoft Excel 2019 using the following formula: B2-B1/365.25, where B2 = date of first day of competition, B1= date of gymnast's birth for participants of the five CC (ACh, OCh, AsCh, ECh, PACh), and for particular finals participants (eight qualified gymnasts from the individual events except for OCh where only six gymnasts for each apparatus qualified): Hoop Finalist' Chronological Age (HFChA), Ball Finalists' Chronological Age (BFChA), Clubs Finalists' Chronological Age (CFChA), and Ribbon Finalists' Chronological Age (RFChA).

Statistics

Statistical analysis was carried out using Statgraphics Centurion software package, version XVIII, Statpoint Technologies, Warrenton, VA, USA. The normality of distribution was examined and since there was non-normality of data and homogeneity of variance was not met (Bartlett test) the Kruskal-Wallis test was used for multiple comparison of mean ranks. The level of significance was set at $p<0.05$. A post-hoc Bonferroni test at the 95% confidence level (CI) for pairwise comparisons between the average ranks of five sport events with the Bonferroni correction statistical significance was set at $p=0.01$. The values in tables are presented as medians (*Mdn*) and interquartile ranges (*IQR, 25% to 75%*). The eta squared, based on the H-statistic was used as the measure of the Kruskal-Wallis test effect size. It was calculated as follows: $\eta^2= (H - k + 1)/ (n - k)$, where H is the value obtained in the Kruskal-Wallis test, k is the number of groups, n is the total number of observations (Tomczak, & Tomczak, 2014). The effect size (η^2) was interpreted as follows: 0.01: small; 0.06: medium; 0.14: large (Cohen 1988).

Results

All-Around Qualification Competition results analysis

The mean ranks produced by the Kruskal-Wallis test, medians, interquartile ranges and the pairwise Bonferroni comparisons that were statistically significant (95% CI) between mean ranks of the AATS, HTS,

BTS, CTS, and RTS for five analyzed sport events are presented in Table 1. The Kruskal-Wallis test showed significant differences between AATS, H = 55.1, $p < 0.001$, $\eta^2 = 0.46$, HTS, H = 50.132, $p < 0.001$, $\eta^2 = 0.416$, BTS, H = 57.71, $p < 0,001$, $\eta^2 = 0.484$, CTS, H = 56.29, $p < 0.001$, $\eta^2 = 0.471$, RTS, H = 43.5, $p < 0.001$, $\eta^2 = 0.356$. The highest ranked events for all variables were ECh and AsCh that were significantly different from the lowest ranked (from the end of leaderboard) ACh and OCh ($p<0.01$). The results of gymnasts competing in PACh were significantly different from both ECh and AsCh in AATS score and only from ECh in BTS and CTS ($p<0.01$).

Table 1. All-around qualification competition total scores.

Total Scores (pts)		Sports Events				
		ACh (n=15)	**OCh** (n=17)	**AsCh** (n=11)	**ECh** (n=52)	**PACh** (n=21)
AATS	MR	19.6[ab]	30.2[ab]	78.2	78.0	49.9[ab]
	Mdn	51.650	55.750	84.900	83.400	69.750
	(IQR)	(32.650-56-000)	(47.560-61.650)	(73.100-89.650)	(75.150-90.350)	(59.300-76.550)
HTS	MR	22.5[ab]	28.8 [ab]	76.9	77.4	52.6
	Mdn	13.000	13.650	20.950	21.300	18.000
	(IQR)	(8.000-15.450)	(12.000-15.050)	(18.750-22.650)	(19.300-23.125)	(14.900-20.400)
BTS	MR	19.0[ab]	31.4 [ab]	74.9	79.9	47.1[a]
	Mdn	12.600	13.600	21.100	21.400	15.500
	(IQR)	(8.100-14.900)	(12.450-16.650)	(18.300-23.550)	(19.450-23.525)	(14.500-19.700)
CTS	MR	19.5[ab]	30.1[ab]	78.5	78.6	49.1[a]
	Mdn	12.550	14.850	21.350	21.850	18.200
	(IQR)	(8.550-15.100)	(13.450-16.060)	(20.350-23.250)	(19.425-24.475)	(15.500-20.800)
RTS	MR	22.4[ab]	33.5 [ab]	80.5	74.4	53.6
	Mdn	10.200	13.050	18.550	18.500	15.750
	(IQR)	(8.550-13.500)	(10.750-15.150)	(16.700-21.250)	(15.875-20.550)	(13.800-18.350)

Note: AATS - All Around Total Score, HTS - Hoop Total Score, BTS - Ball Total Score, CTS - Clubs Total Score, RTS - Ribbon Total Score; MR – mean rank; [a] – different from ECh, [b] – different from AsCh

The Kruskal-Wallis test mean ranks, medians, interquartile ranges and the pairwise Bonferroni comparisons that were statistically significant (95% CI) between mean ranks of the TDS, HDS, BDS, CDS, and RDS for the five analyzed sport events are presented in Table 2. The Kruskal-Wallis test showed significant differences between TDS, H = 59.164, $p < 0.001$, $\eta^2 = 0.497$, HDS, H = 57.6, $p < 0.001$, $\eta^2 = 0.483$, BDS, H = 61.31, $p < 0.001$, $\eta^2 = 0.516$, CDS, H = 59.8, $p < 0.001$, $\eta^2 = 0.503$, RDS, H = 47.6, $p < 0.001$, $\eta^2 = 0.393$. The highest ranked events for all variables were ECh and AsCh, the pairwise comparisons showed that they were different from the lowest ranked (from the end of leaderboard) ACh, OCh, and PACh excepting RDS; the results of gymnasts competing in PACh were also significantly higher ranked from ACh for TDS, HDS, BDS, CDS, RDS ($p<0.01$).

Table 2. All-around qualification competition difficulty scores.

Difficulty Scores (pts)		Sports Events				
		ACh (n=15)	**OCh** (n=17)	**AsCh** (n=11)	**ECh** (n=52)	**PACh** (n=21)
TDS	MR	15.6[abc]	31.6[ab]	82	77.9	50.6[ab]
	Mdn	27.900	35.600	56.100	54.250	44.100
	(IQR)	(17.100-31.400)	(30.600-39.800)	(47.900-59.000)	(48.500-59.050)	(39.200-48.900)
HDS	MR	17.3[abc]	29.2[ab]	80.7	77.6	52.8[ab]
	Mdn	7.000	8.200	14.500	14.300	11.900
	(IQR)	(5.100-8.800)	(7.600-9.800)	(12.800-15.000)	(12.400-15.150)	(9.900-13.200)
BDS	MR	14.7[abc]	32.5[ab]	80.0	79.3	48.7[ab]
	Mdn	6.000	9.200	14.300	14.100	11.500
	(IQR)	(4.000-8.600)	(8.000-10.700)	(12.200-15.500)	(12.500-15.750)	(9.400-12.800)
CDS	MR	16.0[abc]	31.5[ab]	81.2	78.5	49.3[ab]
	Mdn	7.000	10.400	14.800	14.600	11.900
	(IQR)	(4.000-8.900)	(9.100-11.000)	(13.700-15.500)	(12.850-16.200)	(10.700-13.800)
RDS	MR	16.9[abc]	36.4[ab]	85.5	73.3	55.4
	Mdn	5.600	7.400	11.800	11.550	9.700
	(IQR)	(4.300-7.000)	(6.700-9.600)	(10.700-13.700)	(9.850-12.850)	(8.700-11.500)

Note: TDS - Total Difficulty Score, HDS - Hoop Difficulty Score, BDS - Ball Difficulty Score, CDS - Clubs Difficulty Score, RDS - Ribbon Difficulty Score; MR – mean rank; [a] – different from ECh, [b] – different from AsCh, [c] – different from PACh

The mean ranks produced by the Kruskal-Wallis test, medians, interquartile ranges and the pairwise Bonferroni comparisons that were statistically significant at the (95% CI) between mean ranks of the TES, HES, BES, CES, and RES for the five analyzed sport events are presented in Table 3. The Kruskal-Wallis test showed significant differences between TES, H = 42.97, $p < 0.001$, $\eta^2 = 0.441$, HES H = 31.6, $p < 0.001$, $\eta^2 = 0.249$,

BES, H = 44.4, p < 0.001, η^2 = 0.364, CES, H = 40.8, p < 0.001, η^2 = 0.332, RES, H = 35.5, p < 0.001, η^2 = 0.284. The highest ranked events for all variables were ECh and AsCh that were significantly different from the lowest ranked OCh (p < 0.01). The results of gymnasts competing in ACh and PACh were significantly different from ECh in TES and HES, BES, CES, and RES as well (p < 0.01).

Table 3. All-around qualification competition execution scores.

Execution Scores (pts)		Sports Events				
		ACh (n=15)	**OCh** (n=17)	**AsCh** (n=11)	**ECh** (n=52)	**PACh** (n=21)
TES	MR	34.7[a]	27.5[ab]	69.4	77.9	46.8[a]
	Mdn	23.800	19.050	28.300	28.800	24.700
	(IQR)	(15.950-24.900)	(17.300-23.050)	(23.900-30.150)	(25.900-31.625)	(20.100-27.600)
HES	MR	40.0[a]	29.3[ab]	69.2	74.5	50.0[a]
	Mdn	5.600	5.200	6.800	7.150	5.900
	(IQR)	(4.050-6.650)	(4.600-5.850)	(6.350-7.650)	(6.350-7.900)	(5.000-7.200)
BES	MR	33.2[a]	30.3[ab]	67.6	78.9	44.0[a]
	Mdn	5.550	5.300	6.950	7.425	6.000
	(IQR)	(4.100-6.750)	(5.050-6.150)	(6.300-7.850)	(6.850-8.300)	(5.050-7.250)
CES	MR	35.7[a]	26.7[ab]	70.6	76.9	48.7[a]
	Mdn	5.900	4.650	7.000	7.175	6.000
	(IQR)	(4.350-6.700)	(4.350-5.450)	(6.400-7.750)	(6.500-8.125)	(5.200-6.900)
RES	MR	38.0[a]	28.4[ab]	68.1	75.9	49.5[a]
	Mdn	4.850	4.250	6.600	7.100	6.000
	(IQR)	(4.200-6.300)	(3.900-5.850)	(5.900-7.500)	(6.200-7.675)	(4.850-6.750)

Note: TES - Total Execution Score, HES - Hoop Execution Score, BES - Ball Execution Score, CES - Clubs Execution Score, RES - Ribbon Execution Score; MR – mean rank, [a] – different from ECh, [b] – different from AsCh

Finalists' results analysis

The mean ranks produced by the Kruskal-Wallis test, medians, interquartile ranges and the pairwise Bonferroni comparisons that were statistically significant (95% CI) between mean ranks of the apparatuses finalists' total scores: FHTS, FBTS, FCTS, and FRTS for the five analyzed sport events are presented in Table 4. The Kruskal-Wallis test showed significant differences between FHTS, H = 28.7, p<0.001, η^2 = 0.747, FBTS, H = 30.9, p<0.001, η^2 = 0.817, FCTS H = 30.1, p<0.001, η^2=0.79, FRTS H = 29.5, p<0.001, η^2=0.77. The highest ranked events for all variables were ECh and AsCh and were significantly different from the lowest ranked ACh (p<0.01). The results of gymnasts competing in ECh were also significantly higher ranked from OCh in all analyzed variables and from and PACh only in FHTS and FCTS (p<0.01).

Table 4. Descriptive statistics of finalists' total scores. *Comment:* For each final the personal composition of n across five events/apparatus is different.

Finalists' total scores (pts)		Sports Events				
		ACh (n=8)	**OCh** (n=6)	**AsCh** (n=8)	**ECh** (n=8)	**PACh** (n=8)
FHTS	MR	6.6[ab]	13.6[a]	24.0	34.5	17.3
	Mdn	15.025	18.625	22.750	26.950	20.750[a]
	(IQR)	(10.250-18.125)	(17.200-19.800)	(21.125-23.050)	(26.600-27.750)	(17.800-21.100)
FBTS	MR	6.1[ab]	11.3[a]	24.4	34.5	19.1
	Mdn	13.575	17.050	23.150	27.500	20.825
	(IQR)	(11.700-16.125)	(15.600-19.650)	(22.125-23.625)	(26.200-28.550)	(20.300-22.250)
FCTS	MR	7.3[ab]	12.3[a]	25.6	34.5	16.1[a]
	Mdn	14.350	18.400	22.550	27.650	19.750
	(IQR)	(11.525-17.275)	(16.050-20.150)	(21.675-23.700)	(26.350-28.00)	(17.425-20.975)
FRTS	MR	6.3[ab]	11.6[a]	26.2	33.2	18.3
	Mdn	11.650	16.200	20.100	22.350	18.475
	(IQR)	(9.425-14.225)	(14.000-17.050)	(18.825-21.125)	(21.650-22.900)	(16.125-19.275)

Note: FHTS - Finalists' Hoop Total Score, FBTS - Finalists' Ball Total Score, FCTS – Finalists' Clubs Total Score, FRTS - Finalists' Ribbon Total Score; MR – mean rank, [a] – different from ECh, [b] – different from AsCh

The mean ranks produced by Kruskal-Wallis test, medians, interquartile ranges and the pairwise Bonferroni comparisons that were statistically significant (95% CI) between mean ranks of the apparatuses finalists' difficulty scores: FHDS, FBDS, FCDS, and FRDS for the five analyzed sport events are presented in Table 5. The Kruskal-Wallis test showed significant differences between FHDS H=29.9, p<0.001, η^2=0.787,

FBDS H=32.525, p<0.001, η^2 =0.864, FCDS H=30.8, p<0.001, η^2=0.812, FRDS H = 31.0, p<0.001, η^2=0.819. The highest ranked events for all variables were ECh and AsCh that were significantly different from the lowest ranked ACh. The results of gymnasts competing in ECh were also significantly higher ranked from OCh in all analyzed variables and from PACh in FHDS and FCDS (p<0.01).

Table 5. Descriptive statistics of finalists' difficulty scores. *Comment:* For each final the personal composition of n across five events is different.

Finalists' difficulty scores (pts)		**Sports Events**				
		ACh (n=8)	**OCh** (n=6)	**AsCh** (n=8)	**ECh** (n=8)	**PACh** (n=8)
FHDS	MR	6.1[ab]	14.0[a]	25.6	34.4	16.6[a]
	Mdn	8.700	11.900	14.900	17.950	13.400
	(IQR)	(6.050-11.100)	(10.900-12.600)	(14.350-15.150)	(17.600-18.550)	(11.450-12.800)
FBDS	MR	5.3[ab]	11.8[a]	25.0	34.5	19.0
	Mdn	7.200	11.150	15.300	18.500	13.350
	(IQR)	(6.450-9.250)	(10.400-12.200)	(14.700-15.700)	(17.450-19.200)	(12.750-14.750)
FCDS	MR	6.5[ab]	12.5[a]	26.3	34.1	16.4[a]
	Mdn	8.250	11.800	15.500	18.800	13.200
	(IQR)	(6.250-10.550)	(10.200-13.000)	(14.550-16.400)	(18.000-19.050)	(11.550-13.900)
FRDS	MR	5.4[ab]	12.8[a]	27.7	32.7	17.3
	Mdn	6.400	9.800	13.150	14.200	11.250
	(IQR)	(5.200-8.000)	(8.600-10.900)	(12.450-13.700)	(13.650-14.600)	(9.900-11.850)

Note: FHDS - Finalists' Hoop Difficulty Score, FBDS - Finalists' Ball Difficulty Score, FCDS - Finalists' Clubs Difficulty Score, FRDS - Finalists Ribbon Difficulty Score; MR – mean rank, [a] – different from ECh, [b] – different from AsCh

The mean ranks produced by the Kruskal-Wallis test, medians, interquartile ranges and the pairwise Bonferroni comparisons that were statistically significant (95% CI) between mean ranks of the apparatuses finalists' execution scores: FHES, FBES, FCES, and FRES for the five analyzed sport events are presented in Table 6. The Kruskal-Wallis test showed significant differences between FHES, H=22.3, p<0.001, η^2=0.554, FBES, H=25.9, p<0.001, η^2=0.664, FCES, H=22.1, p<0.001, η^2=0.55, FRES, H=20.8, p<0.001, η^2=0.511. The highest ranked event for all variables was ECh that was significantly different from the lowest ranked OCh, ACh for all analyzed variables and from PACh for FHES and FCES (p<0.01).

Table. 6. Descriptive statistics of finalists' execution scores. *Comment:* For each final the personal composition of n across five events/apparatus is different.

Finalists' scores (pts)	execution	**Sports Events**				
		ACh (n=8)	**OCh** (n=6)	**AsCh** (n=8)	**ECh** (n=8)	**PACh** (n=8)
FHES	MR	10.3[a]	13.3[a]	20.4	34.5	17.4[a]
	Mdn	6.100	6.675	7.650	9.075	7.225
	(IQR)	(4.275-7.125)	(6.300-7.300)	(6.800-7.825)	(8.850-9.250)	(6.875-7.550)
FBES	MR	10.5[a]	7.9[a]	21.8	34.1	20.31
	Mdn	6.375	5.900	7.725	9.100	7.575
	(IQR)	(5.425-6.725)	(5.950-7.150)	(7.075-7.375)	(8.350-9.100)	(6.125-7.375)
FCES	MR	10.9[a]	12.9[a]	21.4	34.4	16.3[a]
	Mdn	6.150	6.600	7.200	8.700	6.650
	(IQR)	(5.425-6.725)	(5.950-7.150)	(7.075-7.375)	(8.350-9.100)	(6.125-7.375)
FRES	MR	9.4[a]	11.6[a]	20.9	32.5	21.1
	Mdn	5.300	6.250	6.950	8.150	7.300
	(IQR)	(4.175-6.225)	(5.400-6.450)	(6.500-7.575)	(7.600-8.700)	(6.600-7.525)

Note: FHES - Finalists' Hoop Execution Score, FBES - Finalists' Ball Execution Score, FCES - Finalists' Clubs Execution Score, FRES - Finalists' Ribbon Execution Score; MR – mean rank, [a] – different from ECh

Rhythmic Gymnastics Continental Championships Participants' Chronological Age

Figure 1 illustrates the comparison of chronological age of gymnasts competing in five CC. The Kruskal-Wallis test showed significant differences between chronological age in CC participants, H = 12.6, p<0.01, η^2 =0.078. The pairwise Bonferroni comparisons showed statistically significant differences between the gymnasts of the two highest ranked events: PACh (mean rank: 72,5, Mdn=19.7 years, IQR: 18.3-21.72) and AsCh (mean rank: 70.7, Mdn=19.44 years, IQR: 18.43-20.25), and participants of ACh (mean rank: 39.9, Mdn=17.4 years, IQR: 16.2-19.0); no statistically significant differences in chronological age concerned

gymnasts participating in ECh (mean rank: 60.1, Mdn=18.7 years, IQR: 17.01-21.0), and OCh (mean rank: 44.8, Mdn=18.0 years, IQR: 17.7-18.8) in comparison to participants of other events (95% CI).

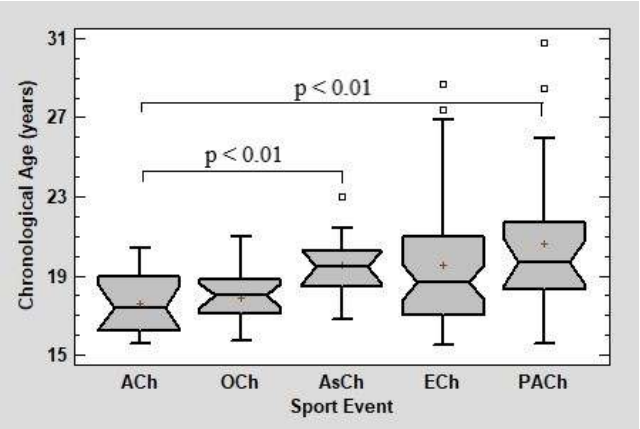

Fig. 1. Chronological age of continental championships participants.

The mean ranks produced by the Kruskal-Wallis test, medians, interquartile ranges and the pairwise Bonferroni comparisons that were statistically significant at the (95% CI) between mean ranks of the apparatuses finalists' chronological age: HFChA, BFChA, CFChA, and RFChA for the five analyzed sport events are presented in Table 7. The Kruskal-Wallis test showed significant differences between BFChA, H = 13.9, $p<0.001$, $\eta^2=0.33$, RFChA H=12.3, $p<0.01$, $\eta^2=0.25$. The pairwise comparison showed that ball finalists competing in ECh were significantly older from ball finalists competing in OCh and ACh, and ribbon finalists competing in ECh were significantly older from ribbon finalists competing in OCh and ACh ($p<0.01$).

Table 7. Descriptive statistics of finalists' chronological age. *Comment:* For each final the personal composition of n across five events/apparatus is different.

Finalists' chronological age (years)		**Sports Events**				
		ACh (n=8)	**OCh** (n=6)	**AsCh** (n=8)	**ECh** (n=8)	**PACh** (n=8)
HFChA	MR	12.1	14.9	21.0	24.1	24.3
	Mdn	17.4	18.4	19.3	20.32	20.35
	(IQR)	(17.12-18.42)	(17.71-19.0)	(18.12-20.18)	(18.48-22.47)	(18.1-27.22)
BFChA	MR	11.9[a]	10.7[a]	21.1	28.7	22.9
	Mdn	18.7	17.86	19.9	21.45	20.35
	(IQR)	(16.66-19.05)	(17.23-18.8)	(18.67-20.84)	(20.12-22.83)	(18.1-25.87)
CFChA	MR	11.3	13.5	22.8	23.5	24.0
	Mdn	17.62	18.26	19.9	20.3	20.35
	(IQR)	(17.26-18.65)	(17.23-19.2)	(18.93-20.84)	(18.47-22.47)	(18.27-27.22)
RFChA	MR	11.1[a]	12.3[a]	20.9	27.6	23.6
	Mdn	17.62	17.86	19.57	21.25	20.27
	(IQR)	(17.12-18.65)	(17.23-18.8)	(18.45-20.18)	(19.58-22.83)	(18.1-27.22)

Note: HFChA - Hoop Finalist' Chronological Age, BFChA - Ball Finalists' Chronological Age, CFChA - Clubs Finalists' Chronological Age, RFChA - Ribbon Finalists' Chronological Age; MR -mean rank, [a] – different from ECh

Discussion

Continental Championships are recognized as an important part of the Olympic cycle because it provides opportunities for Olympic qualification for the highest placed gymnasts from the all-around results of the respective sport event (FIG, 2021). The comparative analysis of results obtained by rhythmic gymnasts competing in five CC in one Olympic cycle showed events that were characterized by the highest or lowest judges' scores. Evidence shows that both ECh and AsCh were the highest ranked events for all analyzed variables of all-around qualifications. The gymnasts competing in ACh and OCh achieved significantly lower scores compared to ECh and AsCh competitors in total scores. The gymnasts competing in PACh also achieved significantly lower results from ECh and AsCh in AATS but for apparatus total scores the significant difference occurred only for HTS and CTS from ECh participants. The greatest differences occurred between AsCh vs. ACh for AATS (33.250 pts), and RTS (8.350 pts), and between ECh vs. ACh for HTS (8.300 pts), BTS (8.800 pts), and CTS (9.300 pts). It was also demonstrated that ECh was the highest ranked event for all analyzed variables of apparatus finals. The comparative analysis across CC demonstrated that the gymnasts competing in ACh, OCh, and PACh (except FBTS and FRTS) achieved significantly lower scores in comparison to ECh competitors in apparatus finalists' total scores, concurrently, ACh finalists achieved significantly lower results

from AsCh finalists. The greatest differences occurred between ECh vs. ACh for FHTS (11.925 pts), FBTS (13.925 pts), FCTS (13.300 pts), and FRTS (10.700 pts). The above differences suggest great diversity in abilities required to satisfy high demands of competition that evaluate the effect of high performance training (Dias, Aleksandrova, Lebre, Bobo & Fink, 2019).

The component of judges scores, such as difficulty, significantly differentiated results of gymnasts competing in analyzed events for all-around qualifications. The gymnasts competing in AsCh and ECh were characterized by significantly higher difficulty scores from those competing in ACh, OCh, and PACh except RDS. Furthermore, the ACh participants achieved significantly lower difficulty scores than PACh participants. The greatest differences occurred between AsCh vs. ACh for TDS (28.200 pts), HDS (6.985 pts), BDS (8.300 pts), CDS (7.800 pts) and RDS (6.200 pts). The differences concerning apparatus finalists' difficulty scores were observed between events similar to those of apparatus finalists' total scores. The greatest differences occurred between ECh vs. ACh for FHDS (9.250 pts), FBDS (11.300 pts.), FCDS (10,550 pts), and FRDS (7.800 pts). Higher scores forming the difficulty score component could result from using technical elements deriving from higher scored groups of difficulties with higher technical value. Secondly the larger number of body and apparatus difficulties performed by gymnasts competing in highly classified competitions in their routines' compositions may have also increased the scores. The redefinition of apparatus difficulty elements in 2017-2020 COP has enabled novelties and creativity with the apparatus in the context of structure and number of technical elements (Chiriac, 2020). Wherein, the routine's composition should not be the series of consecutive difficulties but use specific connections enriching the choreography. According to Hashimoto, Kida, & Nomura, (2017) the hoop, ball, clubs, and ribbon routines' compositions differed significantly in respect to the number of elements from particular groups of body difficulties (balances, leaps, rotations). And, because of the specificity of individual apparatus manipulation and handling technique, they differed significantly in the time related to body difficulties execution: time of execution of one difficulty for clubs and hoop took significantly longer than for ball, and with regard the Ribbon, the time of execution of one difficulty was shorter in comparison to Clubs. The time of execution rotation was significantly longer than time of execution of balance, and balance took significantly longer than jump. Incorporating body and apparatus difficulties into choreography is limited to 90s, taking into account their score value in context of reaching maximally high final score. This also includes considerations for the gymnasts' capabilities. The gymnasts who qualified for the London 2016 Olympic Games presented a lack of body difficulties variation and most often performed *Penché* rotation on a flat foot for hoop (79.2%), clubs (79.2%), and ribbon (76.04%), and for ball *jeté* with a turn jump (79.20%) and *Penché* rotation on a flat foot (75%) (Agopyan, & Örs, 2019). Leandro, Ávila-Carvalho, Sierra-Palmeiro, and Bobo-Arce (2016b) showed that the higher the level of gymnast's achievements or place in the competition ranking, the lower the difference between departure difficulty score declared in the special form by coach and final difficulty score based on the judges' evaluation. This was also found to occur inversely. This tendency concerned differences between departure difficulty scores of technical elements such as jumps, balance, rotations, dynamic elements with rotation and throw, mixed difficulties, and dance steps in three groups of gymnasts clustered according to the place taken at the World Championships in Kiev 2013. In the same competition, the highest contribution in the final score (50%) came from both rotations and dynamic elements with rotation and throw (Leandro, Ávila-Carvalho, Sierra-Palmeiro, & Bobo-Arce, 2016c). Batista, Garganta, & Avila-Carvalho (2017) based on difficulty forms declared by coaches indicated the positive correlation between number of the masteries with non-fundamental group elements and the final score in the 2013 and 2014 Lisbon RG World Cup participants.

The execution scores for the gymnasts competing in ECh all-around qualifications were characterized by significantly higher results than those competing in OCh, ACh and PACh. Additionally, the gymnasts competing in OCh that were the lowest ranked events in execution scores were characterized by significantly lower results from AsCh. The greatest differences occurred between ECh vs. OCh for TES (9.750 pts), HES (1.950 pts), BES (2.125 pts), CES (2.525 pts), and RES (2.850 pts). The comparison of apparatus finalists' execution scores showed that gymnasts competing in ECh had significantly higher results than those competing in OCh, ACh and PACh. The differences between the highest and the lowest ranked event (ECh vs. ACh for FHES, FCES and FRES; ECh vs. OCh for FBES) were 2.975 pts for FHES, 3.200 pts for FBES, 2.550 pts for FCES, and 2.850 pts for FRES, respectively. The quality of execution of ECh finalists was very close to the maximal value of 10 points for FHES and FBES that testifies to the low values of artistic and technical faults deductions. The final score in RG is modeled and influenced by different weights of difficulty and execution scores. According to Örs (2020), the most indicative apparatus scores on total ranking of the 37th RG World Championships (2019) were total ball difficulty score, total ribbon execution score and total hoop execution score that explained 79.3%, 71%, and 44% of the variability of standings, respectively.

The comparative analysis of CC all-around participants' chronological age showed the following gradation from youngest to the oldest: ACh<OCh<ECh<AsCh<PACh. The gymnasts competing in ACh were the youngest and were significantly younger from those competing in AsCh with difference of 2.04 years and from PACh with difference of 2.3 years. But it must be noted here that ACh as the only one of CC was conducted in 2020 that could affect the results. The comparison of apparatus finalists' chronological age showed that participants competed in ECh ball and ribbon finals were significantly older from those competing in OCh and ACh. The observed differences between ECh vs. OCh; ECh vs. ACh for BFChA were 3.59 years and 2.75

years, respectively, and for RFChA they were 3.39 years and 3.63 years respectively. The present study gives the characteristics of particular Continental Championships participants' chronological age. The compared groups constitute the elite of rhythmic gymnasts from five continents, and observed significant differences concerning their chronological age may indicate the occurrence of specific determinants supporting or limiting the development of this sport discipline globally.

These findings need further exploration. Several studies suggested a variety of factors affecting dropout of artistic gymnasts 16 years and over including having other priorities, not being good enough, and being too old (Swan, Souglis, & Andronikos, 2022). It should also be mentioned that the research on relative age in gymnastics, defined as advantages (physical, motor, and cognitive) deriving from advanced developing process in athletes born in the first part of the calendar year, was not observed in context of total scores and its components among rhythmic gymnasts in junior category (Tatlibal, Kutlay, & Oral, 2021). On the other hand, the under-representation of athletes born in the first quarter and the over-representation of athletes born in the fourth quarter of the same year was observed in female gymnasts in the over-15 year old category (Hancock, Starkes, & Ste-Marie, 2015). Further, results based on the group including gymnasts from beginners to senior category indicate that late maturation is desirable in RG, as it positively influences performance scores (Purenović-Ivanović, Popović, & Moskovljević, 2017).

The gymnasts competing in ECh all-around qualification competition were classified in the middle of the ranking concerning the chronological age with a median of 18.7 years but for the finals they were the oldest group for two apparatuses with a median of 21.45 years for BFChA and 21.25 years for RFChA. It can be assumed that older and more experienced gymnasts from this group qualified to finals. Jelaska, Kalinski, and Crnjak, (2017) concluded that winning the Olympic medals in female gymnasts was more influenced by high quality of execution of presented elements and deliberate practice than chronological age, though, the increase of finalists age in comparison to all-arounders was observed. Further investigations of the chronological age effect, undeniably related with sport experience, are needed in context of expert development and sport success in RG.

Conclusions

In conclusion, the comparative analysis of RG results provided an understanding of the differences in all-around and finals total, difficulty, and execution scores across CC of one Olympic cycle. The significant differences in RG CC participants' chronological age were demonstrated in the present study. These provide further understanding of the demographic characteristics of rhythmic gymnasts and their ability to meet the high demands of training and competition at a senior level on five continents. The results of the present study may be used in further analysis of scores and chronological age of rhythmic gymnasts representing particular CC to monitor the trend between front ranks events' competitors and those of lower achievements, and can be informative for coaches, gymnastics federations and such state institutions that are able to organizationally and systemically support RG development.

References

12th Senior Rhythmic Gymnastics Asian Championships, Tashkent, UZB, 8-10 June, 2021. Results Book. Available at: http://www.agu-gymnastics.com/ (accessed: Sep. 15, 2021).

15th African Championships, Sharm El Sheikh, EGY,12-16 March, 2020. Results Book. Available at: http://egypt@egyptgymnastic.com (accessed: Sep. 15, 2021).

37th European Championships in Rhythmic Gymnastics, Varna, BUL, 9-13 June, 2021. Results Book. Available at: https://www.gymnastics.sport/site/events/searchresults.php (accessed: Sep. 15, 2021).

Agopyan, A., & Örs, B. S. (2019). An analysis of variations in body movement difficulty of 2016 Olympic Games rhythmic gymnast candidates. *International Journal of Performance Analysis in Sport*, 19(3): 417-434.

Atiković, A., Kalinski, S. D., & Smajlović, S. (2017). Historical analysis of the chronological age trend of the participants of men's artistic gymnastics who have won medals in the period between 1896 and 2016. *Journal of Physical Education and Sport ® (JPES)*, 17(1), Art 35, pp. 233-239.

Atiković, A., Kalinski, S.D., & Čuk, I. (2017). Change the gymnastics minimum age requirements and the changes that have occurred in major competitions in women's artistic gymnastics. *Acta Kinesiologica*, 11(1): 80-88.

Batista, A., Garganta, R., & Avila-Carvalho, L. (2017). Dance steps, dynamic elements with rotation and throw and mastery elements in rhythmic gymnastics routines. *Science of Gymnastics Journal*, 9(2), 177-189.

Blumenstein, B., & Lidor, R. (2007). The road to the Olympic Games: A four-year psychological preparation program. Athletic Insight. *The Online Journal of Sport Psychology*, 9(4), 15-28.

Boligon, L., Depra, P. P., & Rinaldi, I. P. B. (2015). Influence of flexibility in the execution of movements in rhythmic gymnastics. *Acta Scientiarum. Health Sciences*, 37(2), 141-145.

Chiriac, Ș. (2020). Reshaping Technical Difficulty in Relation to Changes in the Code of Points. *Discobolul – Physical Education, Sport and Kinetotherapy Journal, 59(Supplementary Issue)*: 602-613.

Cohen, J. *Statistical power analysis for the behavioral sciences*. 2nd ed. Hillsdale: Erlbaum; 1988.

Dias, H., Aleksandrova, N., Lebre, E., Bobo, M., & Fink, H. (2019). *Age group development and competition program for Rhythmic Gymnastics.* Lausanne, CH: FIG.

Directives od AsCh, 2021. 12thSenior Rhythmic Gymnastics Asian Championships (INDIVIDUALS AND GROUPS), Tashkent – Uzbekistan, 08-10 June 2021. Available at: https://www.gymnastics.sport/asset.php?id=fidb_10439 (accessed: Sep. 11, 2021).

Directives of ACh, 2020. 15th African Championships Sharm El Sheikh, EGY 12-16 March, 2020 Rhythmic-Aerobic (Junior-Senior). Available at: https://www.gymnastics.sport/site/events/detail.php?id=16393#loaded (accessed: Sep. 09, 2021).

Directives of ECh, 2021. Directives of 37th European Championships in Rhythmic Gymnastics, Varna, BUL, 9-13 June, 2021. Available at: https://www.gymnastics.sport/site/events/searchresults.php (accessed: Sep. 14, 2021).

Directives of OCh, 2021. 2021 Oceania Continental Championships. Gold Coast Sports and Leisure Centre, QLD (AUS) 13th May – 21st May 2021. Available at: https://www.gymnastics.sport/site/events/detail.php?id=16699#loaded (accessed: Sep. 11, 2021).

Directives of PACh, 2021. 2021 Rhythmic and Trampoline Gymnastics Senior Pan American Championships Rio de Janeiro (BRA), June 11-13, 2021. Available at: https://www.gymnastics.sport/asset.php?id=fidb_10182 (accessed: Sep. 14, 2021).

Donti, O., Bogdanis, G.C., Kritikou, M., Donti, A., & Theodorakou, K. (2016). The relative contribution of physical fitness to the technical execution score in youth rhythmic gymnastics. *Journal of Human Kinetics*, 51, 143-152.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, (100): 363-406.

Fédération Internationale De Gymnastique (FIG). (2018). *Code of Points 2017-2020*. Rhythmic Gymnastics Lausanne, CH: FIG. [Updated version 1st of February 2018, valid through 31 Dec. 2021]. Available at: http://www.ploiesti.ro/Gimnastica/html/Metodica/CoP_2017-2020_updated_with_Changes&Errata_Dec.%202017_Valid%2001.01.2018.pdf (accessed: Mar. 11, 2018).

Fédération Internationale De Gymnastique (FIG). (2021). Qualification System – GAMES OF THE XXXII OLYMPIAD – TOKYO 2020. Rhythmic Gymnastics. Available at: https://www.gymnastics.sport/site/rules/rules.php#13 (accessed: Mar. 16, 2021)

Ford, P.R., & Williams, A.M. (2017). Sport activity in childhood: Early specialization and diversification. In: Baker, J., Cobley, S., Schorer, J., & Wattie, N. (Eds.), *Routledge Handbook of Talent Identification and Development in Sport,* New York, NY: Routledge: 117-132.

Furtado, L. N. dos Reis, De Toledo, E., Antualpa K. F., & Carbinatto M. V. (2020). Ballet Movements in Rhythmic Gymnastics Routines: An Analysis from the Last Two Code of Points (2013-2016 and 2017-2020). *Science of Gymnastics Journal*, Vol. 12 Issue 3: 395-406.

Hancock, D.J. Starkes, J.L., & Ste-Marie, D.M. (2015). The relative age effect in female gymnastics: A flip-flop phenomenon. *Int. J. Sport Psychol.*, 46: 714-725.

Harris, D. J., & Atkinson, G. (2009). Ethical standards in sport and exercise science research. *Int. J. Sport Med.* 30: 701–702.

Hashimoto, M., Kida, N., & Nomura, T. (2017). Characteristics of women's rhythmic gymnastics from the perspective of "body difficulty" and performance time. *Advances in Physical Education*, 7(3), 260-273.

Heiniger, S., & Mercier, H. (2018). National Bias of International Gymnastics Judges during the 2013–2016 Olympic Cycle. *arXiv*:1807.10033: 1-9.

Heiniger, S., & Mercier, H. (2021). Judging the judges: evaluating the accuracy and national bias of international gymnastics judges. *Journal of Quantitative Analysis in Sports*, 17(4): 289-305.

Hökelmann, A., Liviotti, G., & Breitkreutz, T. (2013). *Rhythmic Gymnastics*. In: McGarry, T., O'Donoghue, P., & Sampaio, J., editors. Routledge handbook of sports performance analysis. London: Routledge: 475-483.

Jelaska, I., Kalinski, S. D., & Crnjak, T. (2017). Chronological Age among Olympic Women's Artistic Gymnastics. Does it really matter? *Acta Kinesiologica*, 11(2): 108-116.

Law, M.,P., Côté, J. & Ericsson, K.,A. (2007). Characteristics of expert development in rhythmic gymnastics: A retrospective study. *International Journal of Sport and Exercise Psychology*, 5(1): 82-103.

Leandro, C. (2018). Apparatus difficulty in rhythmic gymnastics routines – comparison between 2 Olympic cycles. *Science of Gymnastics Journal*, 10(3): 413-419.

Leandro, C., Ávila-Carvalho, L., Sierra-Palmeiro, E., & Bobo-Arce, M. (2016c). Departure Difficulty Score Vs Final Difficulty Score. The Effect of Performance in Elite Rhythmic Gymnastics. *Athens Journal of Sport*, 3(3): 169-178.

Leandro, C., Ávila-Carvalho, L., Sierra-Palmeiro, E. & Bobo-Arce, M. (2016a). The Evaluation Rules in the View of the Rhythmic Gymnastics Judges. *Journal of Sports Science*, (4): 232-240.

Leandro, C., Ávila-Carvalho, L., Sierra-Palmeiro, E., & Bobo-Arce, M. (2016b). Technical Content of Elite Rhythmic Gymnastics. *Science of Gymnastics Journal*, 8(1): 85-96.

Leandro, C., Ávila-Carvalho, L., Sierra-Palmeiro, E., Bobo, M. (2015). Accuracy in Judgment the Difficulty Score in Elite Rhythmic Gymnastics Individual Routines. *Science of Gymnastics Journal*, 7(3): 81-93.

Oceania Continental Championships. Rhythmic Gymnastics. Carrara, QLD, AUS, 13-16 May, 2021. Results Book. Available at: http://ausgymnasticschamps.com.au/results/ (accessed: Sep. 15, 2021).

Örs, B. S. (2020). The effect of difficulty and execution scores on total ranking during 2019 Rhythmic Gymnastics World Championships. *African Educational Research Journal*, 8(1): 37-42.

Örs, B. S. (2021). A Different Perspective for Coaching and Training Education According to Score Changes During Rhythmic Gymnastics European Championships. *International Education Studies*, 14(5): 63-73.

Popović, R. (2000). International bias detected in judging rhythmic gymnastics competition at Sydney-2000 Olympic Games. *Facta Universitatis Series: Physical Education and Sport*, 1(7): 1-13.

Purenović-Ivanović, T., Popović, R., & Moskovljević, L. (2017). The contribution of pubertal development to performance scores in high-level rhythmic gymnasts. *Acta Gymnica*, 47(3): 122-129.

Purenović-Ivanović, T., Popović, R., Bubanj, S., & Stanković, R. (2016). Rhythmic gymnasts' somatotype: Is it a predictive factor for RG performance? *Acta Kinesiologica*, 10(1), 92-99.

Purenović-Ivanović, T., Popović, R., Stanković, D., & Bubanj, S. (2016). The importance of motor coordination abilities for performance in rhythmic gymnastics. *Facta Universitatis, Series: Physical Education and Sport*, 14(1), 63-74.

Rhythmic and Trampoline Gymnastics Senior Pan American Championships Rio de Janeiro (BRA) June 11-13, 2021. Available at: https://www.gymnastics.sport/site/events/searchresults.php (accessed: Sep. 15, 2021).

Sierra-Palmeiro, E., Bobo-Arce, M., Pérez-Ferreirós, A., & Fernández-Villarino, M.A. (2019). Longitudinal Study of Individual Exercises in Elite Rhythmic Gymnastics. *Frontiers in Psychology*, 10(1496): 1-7.

Starosta, W., & Podciechowska, K. (2009). *Determinants and variability of motor coordination level in rhythmic gymnastics athletes*. [in Polish], International Association of Sport Kinetics (IASK), Warszawa-Poznan.

Sterkowicz K., & Sterkowicz, K. (2005). Comparative analysis of the results at the Olympic games during men's artistic gymnastics between 1988 and 2000. *Revista Mackenzie de Educação Física e Esporte, São Paulo*, 4(4): 113-126.

Sterkowicz-Przybycień K., & Fundament P. (2020). Physical Fitness of Rhythmic Gymnasts Depending on Age and Level of Sports Achievements. *Antropomotoryka. Journal of Kinesiology and Exercise Sciences*, 91(30): 29-36.

Sterkowicz-Przybycień K., Omorczyk, J. (2006). The indices of physical development and body build of young women who practice gymnastics. [in Polish], In: Health promotion in illnesses and disability (ed. Bryc, S.), Annales UMCS, Akademia Medyczna, Lublin, Vol. LX, SUPPL. XVI,745: 235-239.

Sterkowicz-Przybycień, K. (2004). A comparative analysis of the results obtained at the Olympic games in women's artistic gymnastics 1988-2000. *Human Movement*, 5(1): 48-53.

Sterkowicz-Przybycień, K., & Purenović-Ivanović, T. (2021). What are the most important activities in a rhythmic gymnastics coach profession? An exploratory analysis of coaches' opinions. *Journal of Physical Education and Sport ® (JPES)*, 21(3), 2010-2018.

Swan, I., Souglis, A., & Andronikos, G. (2022). Investigating the reasons for dropping out by competitive artistic gymnastics. *Journal of Physical Education and Sport ® (JPES)*, 22 (1): 55-66.

Tatlibal, P., Kutlay, E., & Oral, O. (2021). Is There a Relative Age Effect in the Competition Total Scores and Its Components of Junior Individual Rhythmic Gymnasts? *P J M H S*, 15(10): 2986-2990.

Toledo, E., & Antualpa, K. (2016). The appreciation of artistic aspects of the Code of Points in rhythmic gymnastics: an analysis of the last three decades. *Rev Bras Educ Fís Esporte, (São Paulo)*, 30(1):119-131.

Tomczak, M., & Tomczak, E. (2014). The need to report effect size estimates revisited. An overview of some recommended measures of effect size. *Trends in Sport Sciences*, 1(21):19-25.