

KEY PERFORMANCE INDICATORS OF INDIVIDUAL MEDALISTS IN RHYTHMIC GYMNASTICS COMPETING AT THE 2020 OLYMPIC GAMES

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Abstract

This study aims to analyze the contribution of each apparatus' score component to the overall score and to identify the key performance indicators that distinguish medalists from non-medalists among the 10 finalists in rhythmic gymnastics at the 2020 Olympic Games, Tokyo. Medalists (n=3) and non-medalists (n=7) were separated in the sample. Each apparatus (hoop/ball/clubs/ribbon) had seven components [body difficulty (DB), apparatus difficulty (DA), D total, artistic execution (EA), execution technical (ET), E total, total score (TS) of apparatus, and a total final score (TFS-sum of four apparatus scores)]. A total of 350 scores were analyzed. The Mann–Whitney U tests and Cohen's d effect size (ES) calculation were used to calculate differences. The following variables were determined to differentiate the TFS of the medalist and the non-medalist gymnasts: the large effect with Ball-DA/D total/EA/E total/TS (ES=1.550–1.879), Clubs-DA/D total/EA/TS (ES=0.316–2.080), Hoop-DA/D total/TS (ES=1.897–2.316), Ribbon-EA (ES=1.879), and with a low-effect Clubs-AD (ES=0.316) components. Hoop-DA and Hoop-D-TS (ES=2.316, $p < 0.05$) have the greatest impact, while all DB and ET scores ($p > 0.05$) have no effect on TFS. The impact of apparatus-specific score components on Olympic medal outcomes varies significantly. Notably, difficulty scores (both total and apparatus-specific) and artistic scores emerged as key performance indicators for achieving high total scores and securing a medal in rhythmic gymnastics at the Olympic Games. Coaches should prioritize choreography planning aimed at enhancing difficulty, particularly the apparatus difficulty score, while also focusing on enhancing artistic quality through flawless execution of routines by the gymnasts.

Keywords: apparatus difficulties, body difficulties, individual routines, Olympic medalists, performance analysis, rhythmic gymnastics.

INTRODUCTION

Rhythmic gymnastics (RG) is an Olympic sport in which gymnasts present

choreography combining elements of art, classical ballet and sport in individual and

group events (Agopyan, 2014, 2021; Gram & Bo, 2020). RG was first introduced in the Olympic Games in the individual event at the 1984 Los Angeles OG, followed by the group events at the 1996 Atlanta OG (Hamza & Ahmed, 2020; Kwitniewska et al., 2009).

Gymnasts in RG are expected to present body and apparatus (rope, hoop, ball, clubs, and ribbon) elements in competitions with delicacy and artistic features, without errors, according to the discipline-specific rules and difficulty level. An individual rhythmic gymnast's routine lasts 75 to 90 seconds and is performed at high intensity (Zetaruk et al., 2006), requiring the incorporation of complex apparatus and body skills into the choreography (Kwitniewska et al., 2009). RG competition rules are known as the Code of Points (CoPs) in this complex structure. The FIG-RG Technical Committee CoP determines the CoP, which is updated every 4 years during each Olympic cycle (Örs, 2021; Toledo & Antualpa, 2016). The main aim and target of the RG-CoP rules are to provide a more objective evaluation of compounds affected by the quantity and quality criteria and parameters to evaluate gymnasts' difficulties, execution, and artistry.

The evaluation of RG (Rhythmic Gymnastics) routines consists of four major components that influence a routine's total score:

- Difficulty Score: This score reflects the combined difficulty of body difficulties (DB: balances, rotations, and jumps/leaps) and the difficulty of apparatus (DA: technical apparatus elements performed with specific criteria related to the apparatus).
- Artistry (EA) Score: The artistry score is an assessment of the athlete's

artistic performance, based on the standard of aesthetic perfection.

Execution Technique (ET) Score: This score is based on the execution of elements involving both the body and the apparatus. These elements should be performed with aesthetic and technical perfection.

The total score for a routine is determined by adding the difficulty, artistry, and execution scores, and then subtracting any penalty scores (FIG, 2018).

All of these different components are evaluated by technically expert judges, and the ability to perform a difficult exercise with a high execution score is the primary determinant of success in RG (Agopyan & Örs, 2019). Considering all of these structures, RG is a sport that develops various motor abilities (whole-body coordination, dynamic balance and static balance, sense of kinaesthesia, whole-body movement in time, and hand-eye coordination) and perceptual abilities (whole-body reaction time, anticipation of coincidence, and depth perception; Purenović-Ivanović et al., 2016). Because of these structures, RG is defined as a sport that requires early athlete selection, intensive training during childhood and adolescence, and early termination of the sports career (Rutkauskaitė & Skarbalius, 2012). Successful performance in RG requires many years of practice and consistency in training (Ivanova, 2022).

One of the most important goals in this long and difficult process is to win a medal by competing in the OG. Gymnasts can qualify to compete at the OG, the most prestigious competition in their career, as early as at the age of 16. However, it is extremely difficult to compete at the OG, let alone win a medal. Gymnasts must train systematically to maximize their technical development. It is also important to be able

to quickly adapt to the competition rules, which change every 4 years, and to adjust their choreography accordingly.

After becoming a world-class Olympic discipline, RG has evolved dramatically. Changes in competition rules are also implemented to encourage the development of sports (Agopyan, 2014; Ávila-Carvalho et al., 2012), and revisions of the CoP improve athlete's technical skills. This sport has undergone significant changes in recent years, owing primarily to an increase in technical skill as a result of the constant revision of the requirements imposed by the FIG-CoP rules (Chiriac, 2020).

Most published studies on the content of RG routines include an understanding of the number and level of difficulty elements in each apparatus (Agopyan, 2014, 2021; Agopyan & Örs, 2019; Ávila-Carvalho et al., 2012; Ávila-Carvalho, Leandro, & Lebre, 2010; Batista et al., 2019; Leandro et al., 2016). On the other hand, few studies in the literature have examined the influence of total score components on the final scores in group and individual events at world championships (WCh) and world cups (Kutlay et al., 2021; Örs, 2020; Tatlibal et al., 2021, 2022). Some studies place emphasis on the contribution of each type of element evaluated by the judges comprising the final score (Tatlibal et al., 2022; Örs, 2020). Each apparatus and each score component do not have the same impact on qualifications. It has been noted that the total ball difficulty score has one of the largest effects on rankings in senior RG-2019 WCh (Örs, 2020), whereas the clubs difficulty score had the best results in junior RG-2019 WCh (Tatlibal et al., 2022). It is also concluded that establishing a balance between the impact of total score components for each apparatus on final scores may enhance routine integrity and

artistic expression (Tatlibal et al., 2022). These results may vary depending on the nature of gymnastics as a sport, the participating countries, the athletes, and the dynamics of each competition. Moreover, changes in the CoP after each Olympics can lead to divergent outcomes due to disparities in rules (Kosova & Kosova, 2021).

Therefore, it is proposed that future studies investigate whether the difference between difficulty scores and final difficulty scores is influenced by the type of apparatus (Leandro et al., 2016). In rhythmic gymnastics, routine elaboration entails the choices scored and considered by the CoP, reflecting what is practically achievable by the gymnast. From this perspective, comprehending the performance indicators of medal-winning gymnasts, including body and apparatus difficulties, artistic components in the choreography, and excellent execution, is crucial for making adjustments in the periodization and training regimens of gymnasts to ensure well-prepared participation in future international events.

Despite the significance of prior studies in elucidating the effects of RG total scores on rankings, there remains a need to conduct further research focused on understanding the performance of Olympic-level medalist gymnasts from diverse perspectives and considering various key performance indicators.

To the best of our knowledge, no study has investigated the scores of the top three gymnasts during an Olympic Games (OG). Given that only three medals are awarded at the OG, analyzing the scores of the top three gymnasts can yield crucial insights for coaches in choreography preparation. It is also essential to comprehend the score levels achieved by Olympic athletes in

rhythmic gymnastics routines (hoop, ball, clubs, and ribbon) and the contributions of each component, including difficulty, artistic, and execution, to adapt to evolving standards, grasp the foundations of high-level performance, and assist coaches in refining their training plans. In the light of this information, this study aims to analyze the contribution of the score components of each apparatus to the overall score in the RG Summer OG-2021 (officially known as XXXII OG, Tokyo 2020) competitions and to identify the key performance indicators that distinguish the medalists from non-medalist finalists. It is hypothesized that non-medalists' scores and the subcomponents of all apparatuses may have a significant impact on the total score of medalist gymnasts.

METHODS

This study is designed as both a descriptive and inferential analysis, utilizing publicly available official data from the Tokyo 2020 Summer Olympics (OG). The primary focus of this study is to examine the impact of the total score components of each apparatus (hoop, ball, clubs, and ribbon) on the final performance scores of both medalist and non-medalist individual senior Olympic finalist rhythmic gymnasts. Demographic characteristics of the gymnasts and competition data were extracted from the official website of the International Olympic Committee (IOC, <https://olympics.com/tokyo-2020/olympic-games/en/results/rhythmic-gymnastics/reports.htm>) and Official Results Book of the OG in Tokyo 2020 FIG (<https://olympics.com/tokyo-2020/olympic-games/en/results/rhythmic-gymnastics/reports.htm>).

This study was conducted as an observational study with publicly available data in an unprocessed format and was not collected through experimentation. Competition data were obtained from the result books of the 2020 Summer OG in RG (links provided in the Participants section). Therefore, there are no ethical concerns regarding the use of data from open access websites (Morley & Thomas, 2005). Additionally, in accordance with the European General Data Protection (Regulation, 2016) legislation, all gymnasts participating in the present study have been coded to safeguard their identities.

The data of the participants in the study were taken from the official competition scores of the senior individual elite rhythmic gymnasts who finished the 2020 Summer OG as the top 10 finalists. The event was postponed to summer 2021 due to the Covid-19 pandemic and was held in Tokyo (Japan) on August 6 and 7, 2021.

The individual all-around qualification competitions for the 2020 Summer Olympics featured 26 rhythmic gymnasts. Among them, 10 rhythmic gymnasts secured spots as finalists based on their qualification results. These finals were held to determine the first, second, and third-place gymnasts in the senior individual rhythmic gymnastics standings at the 2020 Summer Olympics. These 10 gymnasts represented Israel (ISR, two gymnasts), the Russian Olympic Committee (ROC, two gymnasts), Belarus (BLR, two gymnasts), Bulgaria (BUL, one gymnast), and Ukraine (UKR, two gymnasts). The gymnasts' ages ranged from 19 to 22 years old, with an average age of 20.32 ± 1.54 years.

The gymnasts scores were divided into two groups for the analysis: medalists ($n = 3$), i.e., the top three gymnasts (the recipients of the OG medals), and non-

medalists ($n = 7$), i.e., the remaining seven gymnasts.

Data were collected from a total of 40 routines, which included senior individual all-around finals 2020 Summer OG hoop, ball, clubs, and ribbon apparatus scores. Difficulty (D) and execution (E) scores of each apparatus and subcomponents of these scores were analyzed. The D and E scores and subcomponents were determined using the RG-CoP 2017-2021 (FIG, 2018) as follows:

- The D score is divided into two subgroups: body difficulty (DB) and apparatus difficulty (DA).
- The E score is divided into two subgroups: artistic execution deductions (EA) and execution technical deductions (ET).

The total score of each apparatus is calculated by adding the D total and E total scores (if there is a penalty, it is deducted from the final score of the apparatus).

The research data consisted of eight components for each apparatus: DB, DA, D total, EA, ET, and E total and, for the hoop, ball, clubs, and ribbon, the total apparatus score for each of the four apparatuses and the total final score (the sum of four apparatus scores). During the current study, 350 scores were analyzed. The following RG-CoP 2017-2021 (FIG, 2018) scores were calculated:

1. DB scores include the number and value of the DB and dance steps (DSs).
2. DA scores include the number and technical value of dynamic elements with rotation (DER) and apparatus difficulty. DA scores of each apparatus were evaluated separately.
3. D total scores are calculated by adding the DB and DA scores for each apparatus
4. EA scores include artistic component penalties for each apparatus and include the following features: unity of composition

(guiding idea and connections), music and movement (rhythm: dynamic changes), body expression (the body segments or the face; two different body waves), variety (in the use of directions and trajectories, floor area, level, planes, directions, techniques of apparatus elements), and fundamental apparatus elements.

5. ET scores include penalties for technical errors in body movements and apparatus elements for each apparatus. Both EA and ET components are scored on a scale of 20.00 points, with each component accounting for 10.00 points.

6. E total scores are included by the addition of the EA and ET scores for each apparatus.

7. The total score for each apparatus is calculated by adding the D total score (DB + DA scores) and the E total score (EA + ET scores); any penalties are deducted from the final score for each apparatus.

8. The total final score (the sum of all scores) is calculated by adding the total scores for the hoop, ball, clubs, and ribbon. This final score determines the Olympic champion.

For each variable, the minimum, maximum, mean, and standard deviation (SD) were calculated. The Shapiro–Wilk test was used to confirm the normality of the quantitative variables, and it was determined that all variables had a normal distribution. Due to the small number of participants, nonparametric tests (Mann–Whitney U test) were used to evaluate the significance of differences between the two groups' variables (medalists and non-medalists). The effect sizes (ESs) calculated using the Cohen's d calculation, which was used when the parameter had a normal distribution, were interpreted as small when results were 0.20 or greater; medium when results were 0.50 or greater, and large when

results were 0.80 or greater (Cohen, 1992). All statistical procedures were carried out using SPSS (Version 25.0, Chicago, IL), with the level of significance set to $p > 0.05$.

RESULTS

The means and standard deviations of the OG scores of the medalist and non-medalist gymnast's according to the components in all apparatus are presented in Table 1. Comparisons between groups based on components in all apparatus are presented in Table 2. It was determined that there were statistically significant differences ($p < 0.05$; Table 2) between the medalist and non-medalist group scores in terms of DA (hoop, ball and sum of all apparatus), D-Total (hoop, ball, clubs, sum of all apparatus), EA (ball, clubs, ribbon, sum of all apparatus) E-Total (ball, sum of all apparatus) and Total Scores (hoop, ball, clubs, sum of all apparatus) These differences were found to be in favor of the

medalist group and the effect sizes were also large ($ES = 1.550$ – 2.316). It was determined that for the clubs, the DA score of medalist gymnasts was higher ($p < 0.05$) and the effect size ($ES = 0.316$) was smaller compared to non-medalist group scores.

There were no statistical differences ($p > 0.05$) between the medalist and non-medalist in terms of DB (hoop, ball, clubs, ribbon, sum of all apparatus), DA (ribbon), D-Total (ribbon), EA (hoop), ET (hoop, ball, clubs, ribbon, sum of all apparatus), E-Total (hoop, clubs, ribbon), and Total Score (ribbon) (Table 2). On the basis of apparatus scores, it was determined that the medalist gymnasts had higher performance scores in hoop-DA ($ES = 2.316$) (Figure 1a) and hoop-D-total ($ES = 2.316$) (Figure 1b) with the largest effect size. These differences in Hoop-DA (1.519 points) and Hoop-D-total (1.543 points) scores were found to be the most significant differences between the medalist and the non-medalist gymnasts (Table 2).

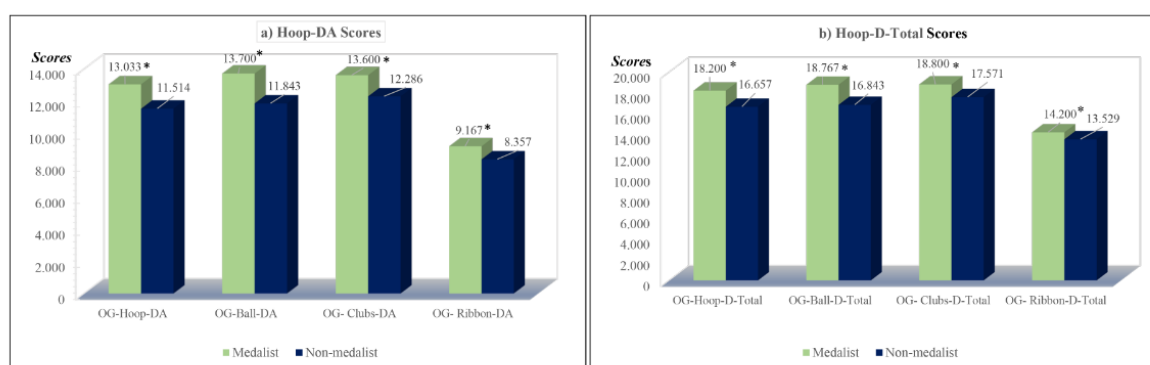


Figure 1. The hoop DA (Figure 1a) and hoop D-total (Figure 1b) scores have the greatest effect on the overall score. The first three gymnasts with Olympic medals had statistically significant and higher hoop DA (Figure 1a) and hoop D total (Figure 1b) scores than non-medalist gymnasts (* $p < 0.05$).

Table 1

Descriptive statistical analysis of the choreographic scores on all apparatuses the individual rhythmic gymnastics finalists participating in the 2020 Summer OG final (n = 10).

Apparatus Variables Scores	OG-DB	OG-DA	OG-D-Total	OG-EA	OG-ET	OG-Total E	Total Score
Hoop							
Mean ± SD	5.150±0.251	11.970±0.938	17.120±0.984	0.560±0.250	0.888±0.239	8.552±0.445	25.673±1.351
Min-Max	4.700-5.500	10.600-13.300	15.500-18.500	0.200-1.000	0.450-1.200	8.000-9.350	23.700-27.550
Ball							
Mean ± SD	5.020±0.361	12.400±1.156	17.420±1.369	0.630±0.343	0.985±0.528	8.385±0.819	25.805±2.065
Min-Max	4.300-5.600	10.900-14.000	15.500±19.100	0.200-1.100	0.400-2.000	7.200-9.300	23.000-28.300
Clubs							
Mean ± SD	5.260±0.375	12.680±0.733	17.940±0.793	0.510±0.311	0.740±0.313	8.750±0.601	26.690±1.327
Min-Max	4.700-5.800	11.800-13.900	16.900-19.400	0.200-1.100	0.300-1.250	7.800-9.500	24.900-28.650
Ribbon							
Mean ± SD	5.130±0.306	8.600±0.899	13.730±0.884	0.660±0.212	1.205±0.416	8.135±0.592	21.805±1.414
Min-Max	4.500-5.400	6.800-10.000	12.000-15.000	0.300-1.000	0.500-2.000	7.000-9.200	19.550-24.000
Total Final Score (Sum of four apparatus)							
Mean ± SD	20.560	45.650 ±3.049	66.210±3.321	2.360±2.582	3.818±1.134	33.823±2.031	99.973±5.190
Min-Max	±1.046 18.500- 21.900	42.400-51.100	62.300-72.000	1.200-4.100	1.850-5.725	31.400- 36.950	93.350- 107.800

OG: Olympic games; DB: Body difficulty; DA: Apparatus difficulty; D-Total: Total difficulty score; EA: Execution artistic score; ET: Execution technique score; Total E: Total execution score

Table 2 :

Descriptive statistical analysis values of the choreographic scores on all apparatuses between the medalist and non-medalist individual rhythmic gymnasts participating in the 2020 Summer OG final (n = 10.)

		MEDALIST (n=3)				NON-MEDALIST (n=7)				p-value	Effect size
		Min	Max	Mean	SD	Min	Max	Mean	SD		
H O O P	OG-Hoop-DB	4.900	5.500	5.167	0.306	4.700	5.400	5.143	0.251	1.000	0.072 ⁺
	OG-Hoop-DA	12.800	13.300	13.033	0.252	10.600	12.600	11.514	0.701	0.017*	2.316 [§]
	OG-Hoop-D-Total	17.900	18.500	18.200	0.300	15.500	17.500	16.657	0.768	0.017*	2.316 [§]
	OG-Hoop-EA	0.300	0.400	0.367	0.058	0.200	1.000	0.643	0.257	0.084	1.285 [§]
	OG-Hoop-ET	0.600	1.000	0.750	0.218	0.450	1.200	0.946	0.237	0.240	0.773 [§]
	OG-Hoop-E-Total	8.600	9.050	8.883	0.247	8.000	9.350	8.411	0.446	0.084	1.285 [§]
	OG-Hoop-Total Score	26.500	27.550	27.083	0.535	23.700	26.850	25.068	1.105	0.030*	1.879 [§]
B A L L	OG-Ball-DB	5.000	5.100	5.067	0.058	4.300	5.600	5.000	0.440	0.908	0.072 ⁺
	OG-Ball-DA	13.200	14.000	13.700	0.436	10.900	13.300	11.843	0.856	0.030*	1.879 [§]
	OG-Ball-D-Total	18.200	19.100	18.767	0.493	15.500	18.600	16.843	1.198	0.030*	1.879 [§]
	OG-Ball-EA	0.200	0.300	0.233	0.058	0.300	1.100	0.800	0.252	0.020*	2.080 [§]
	OG-Ball-ET	0.400	0.600	0.500	0.100	0.400	2.000	1.193	0.497	0.067	1.411 [§]
	OG-Ball-E-Total	9.200	9.300	9.267	0.058	7.200	9.300	8.007	0.671	0.049*	1.550 [§]
	OG-Ball-Total Score	27.500	28.300	28.033	0.462	23.000	27.900	24.850	1.667	0.029*	1.879 [§]
C L U B S	OG-Clubs-DB	4.800	5.500	5.200	0.361	4.700	5.800	5.286	0.406	0.732	0.217 ⁺
	OG- Clubs-DA	13.000	13.900	13.600	0.520	11.800	12.900	12.286	0.334	0.016*	0.316 [§]
	OG- Clubs-D-Total	18.300	19.400	18.800	0.557	16.900	18.300	17.571	0.559	0.022*	2.080 [§]
	OG- Clubs-EA	0.200	0.200	0.200	0.000	0.200	1.100	0.643	0.276	0.034*	1.705 [§]
	OG- Clubs-ET	0.350	0.550	0.467	0.104	0.300	1.250	0.857	0.301	0.086	1.285 [§]
	OG- Clubs-E-Total	9.250	9.450	9.333	0.104	7.800	9.500	8.500	0.544	0.086	1.285 [§]
	OG- Clubs-Total Score	27.600	28.650	28.133	0.525	24.900	27.800	26.071	1.030	0.030*	1.879 [§]
R I B B O N	OG-Ribbon-DB	4.800	5.400	5.033	0.321	4.500	5.400	5.171	0.315	0.563	0.366 ⁺
	OG- Ribbon-DA	7.900	10.000	9.167	1.115	6.800	9.200	8.357	0.755	0.304	0.686 ^γ
	OG- Ribbon-D-Total	12.800	15.000	14.200	1.217	12.000	14.100	13.529	0.723	0.304	0.686 ^γ
	OG- Ribbon-EA	0.300	0.600	0.433	0.153	0.600	1.000	0.757	0.151	0.028*	1.879 [§]
	OG- Ribbon-ET	0.500	1.300	0.967	0.416	0.950	2.000	1.307	0.401	0.424	0.521 ^γ
	OG- Ribbon-E-Total	8.300	9.200	8.600	0.520	7.000	8.450	7.936	0.530	0.202	0.864 [§]
	OG-Ribbon-Total Score	21.100	24.000	22.800	1.513	19.550	22.450	21.379	1.237	0.210	0.864 [§]
A L A P P	OG- All App-DB	19.600	21.500	2.467	0.961	18.500	21.900	20.600	1.152	0.569	0.366
	OG- All App -DA	46.900	51.100	49.500	2.272	42.400	45.600	44.000	1.279	0.016*	2.316 [§]
	OG-All App -D-Total	67.200	72.000	69.967	2.483	62.300	67.500	64.600	2.101	0.030*	1.879 [§]
	OG- All App -EA	1.100	1.4000	1.233	0.153	1.500	4.100	2.843	0.814	0.016*	2.316 [§]
	OG- All App -ET	1.850	3.100	2.683	0.722	2.800	5.725	4.304	0.915	0.051	1.550
	OG- All App -E-Total	35.500	36.950	36.083	0.765	31.400	35.700	32.854	1.530	0.030*	1.879 [§]
	OG-All App -Total Score	102.700	107.800	106.050	2.902	93.350	102.100	97.368	3.350	0.017*	2.316 [§]

OG: Olympic games; DB: Body difficulty; DA: Apparatus difficulty; D-Total: Total difficulty score; EA: Execution artistic score; ET: Execution technique score; E-Total: Total execution score

[§] Large effect size; ^γmedium effect size; ⁺small effect size; p<0.05* effect size= Cohen's d

It was determined that all score components and the total result score in the ribbon were at the lowest level compared with the other apparatus. All gymnasts received the highest score in the club apparatus.

DISCUSSION

The current study compared the contribution of each apparatus score components to the overall score and to identify the key performance indicators that distinguish medalist and non-medalist RG finalists in the 2020 Summer OG Tokyo.

Analyzing the context of difficulty elements was not within the scope of the study's main goal. Our research was based on the judges' evaluation scores for the finalist gymnasts during the competition. The results revealed that medalist gymnasts had significantly higher scores than non-medalists on all apparatuses when performance criteria were considered, and the research hypotheses were partially confirmed.

“The primary finding of this study reveals that when considering the cumulative performance across all apparatuses in winning an Olympic medal in rhythmic gymnastics, the influence of total apparatus difficulty, overall difficulty, and execution artistry scores on the final total score is substantial. However, it was discovered that the effects of score components on the total final score vary depending on each apparatus. It was found that the ball apparatus had the greatest impact on the total score with five different components (DA, D-Total, EA, E-Total, Total scores). Following closely were the clubs apparatus with four components (DA, D total, EA, and Total score) and the hoop with three components (DA, D total, and

Total score). Finally, among the four apparatuses with only one component (execution artistry), the ribbon had the least impact. Furthermore, the hoop-DA and D total components had the greatest impact on the total score.”

Gymnasts attempt to adapt quickly to major changes in RG-CoP that are amended every 4 years by the FIG-RG technical committee. They try to gain grounds by making strategic changes in their choreographies (Sierra-Palmeiro et al., 2019). Changes in the RG-CoP may have varying effects on the number of elements performed and the final scores (Sierra-Palmeiro et al., 2019). The complexity of the interaction between the gymnast and the apparatus or the degree of coordination during the difficulties could be the reason for the RG-CoP updates (Leandro, 2018). For this reason, it is crucial in modern RG to perform strategically well-planned routines (Hashimoto et al., 2017). Olympic gymnasts aiming for the highest scores in RG perform routines with higher levels of difficulty combined with good execution (Agopyan, 2014). The current study found that medalist and non-medalist gymnasts had similar, high levels of body difficulty average scores (5.00–5.20 points). This finding indicates that Olympic gymnasts have similar abilities when it comes to performing body difficulties. The results of the current study also show that body difficulty score is not the most important factor in determining an Olympic medal. On the other hand, the first top three gymnasts with Olympic medals had statistically significant and higher DA average scores (9.1–13.7 points) than non-medalist gymnasts (8.3–12.8 scores). Dynamic elements with rotation (DER) are one of the elements evaluated within the scope of DA, with a value of 0.20.

According to the RG-CoP 2017–2021 (FIG, 2018), gymnasts are permitted to perform a minimum of one and a maximum of five DERs in a single routine. Furthermore, many gymnasts can perform the DER elements with higher values (e.g., 0.50–1.00 points or higher) by adding additional criteria based on the apparatus characteristic. In addition, apparatus difficulty, with values ranging from 0.20 to 0.40, is another crucial aspect within the domain of DA. Under the RG-CoP 2017–2021 (FIG, 2018), these elements were permitted to be performed without any limit within a single routine. Notably, gymnasts with Olympic medals scored approximately 1.30–1.90 points higher in the DA component compared to non-medalists, indicating their ability to execute elements with significantly higher criteria or numbers. These findings also corroborate assertions in the existing literature (Chiriac, Teodorescu, & Bota, 2020) that gymnasts tend to incorporate a substantial number of high-difficulty apparatus elements to attain the best possible results.

Furthermore, our study revealed that the influence of the DA component on the total score, except for ribbon, exhibited a high impact in the hoop and ball routines but a lower impact in clubs. This discrepancy suggests that the effect of DA scores on the total score varies depending on the specific apparatus. In comparison to ribbon, hoop, ball, and clubs offer gymnasts the opportunity to execute a wide variety of DA elements, including DER and apparatus difficulty. The frequent use of rolls in apparatus difficulty with hoop and ball, along with their adaptability for use in different ways with clubs, may explain the effectiveness of apparatus difficulty in achieving higher scores. Additionally, the ease with which various throwing and

catching criteria, such as those occurring outside the visual area and without the use of hands, can be executed in these three apparatuses (hoop, ball, and clubs) during DER and apparatus difficulty likely contributes to this divergence.

Individual skill performance in RG varies with difficulty level and requires good coordination between body and apparatus elements (Tsopani et al., 2012). The demanding coordination requirements associated with execution of apparatus difficulty elements are particularly important (Sierra-Palmeiro et al., 2019) for achieving better competitive performance (Chiriac et al., 2020). Additionally, the findings of this study underscore that medalists excel in executing apparatus difficulties in the hoop, ball, and clubs, leading to higher scores. This outcome emphasizes the importance of designing training programs to enhance apparatus-specific difficulty scores.

Another important finding of the current study was that Olympic medalists (18.2–18.8 points) had significantly higher total difficulty scores in the hoop, ball, and clubs than non-medalists (16.6–17.5 points). This finding indicates that the total difficulty score, which is the sum of BD and DA scores and includes body and apparatus difficulty, is one of the most important factors in determining the Olympic medal.

The findings of this study indicate that, on an apparatus-specific basis, the hoop had the most significant impact on the total difficulty score, followed by the clubs and ball, in that order. This result aligns with Örs's observation in 2020 that the total difficulty score, regardless of apparatus type, served as the most robust predictor of success in rhythmic gymnastics at the 2019 World Championships (WCh). Furthermore, Örs (2020) discovered that the

difficulty score in routines performed with the ball had the most substantial influence on gymnasts' qualifying scores and rankings, accounting for 79.3% of the variation. Additionally, Tatlibal et al. (2022) emphasized the significance of the difficulty score in clubs routines as one of the key factors affecting the final score at the 2019 Junior World Championships.

Existing literature studies emphasize that the connection between the quantity of technical elements and the final score in rhythmic gymnastics is contingent on the specific apparatus involved (Sierra-Palmeiro et al., 2019). Moreover, an analysis of World Championships data spanning the last two decades has disclosed that comprehensive changes in the CoP influence the number of technical elements performed, leading to varying results scores across different apparatuses (Sierra-Palmeiro et al., 2019). These findings are consistent with the results of our study.

Rhythmic gymnastics (RG) is a sport that demands the presentation of technical, aesthetic, and artistic qualities in an optimal manner, encompassing both form and execution (Elce et al., 2022). In our study, we assessed execution scores, considering artistic and technical components, alongside the difficulty score components in the choreography. Judges evaluate the artistic execution scores in competitions based on several subcomponents, including the choreographic structure, the integration of body/apparatus movements with music, dynamism, variety in the use of apparatus and space, and the overall quality of meeting these requirements.

Our study revealed that the artistic execution score's impact on the final total score varies depending on the apparatus when determining Olympic rankings. With the exception of the hoop, we found that the

artistic execution score significantly influences the final total score in three apparatuses. Notably, medalist gymnasts demonstrated substantially lower deduction scores (ranging from 0.2 to 0.4 points) with a more substantial effect on ball, clubs, and ribbon routines compared to non-medalist gymnasts (where deductions ranged from 0.6 to 0.8 points).

While both DB (Difficulty of Body) and DA (Difficulty of Apparatus) components are objectively evaluated in choreographies, it is widely recognized that the evaluation of artistic features is more subjective. Notably, differences in the artistry execution (EA) scores suggest that the artistic performances of medalist gymnasts, particularly in choreographic structure and the execution of elements in line with aesthetic standards, approach perfection. These findings underscore the significance of the artistic execution average total scores in ball, clubs, and ribbon routines as pivotal factors in determining medal status, with similarly high effect sizes.

Conversely, our study found no significant differences in technical execution scores between groups. Surprisingly, the execution technique scores of medalist gymnasts (ranging from 0.4 to 0.9 points) for all apparatuses were lower than those of non-medalist gymnasts (ranging from 0.8 to 1.3 points). This discovery implies that Olympic gymnasts perform comparably in terms of body-specific and apparatus-specific technical elements. While there may be no statistical difference in the technical execution scores, it's important to acknowledge the significance of even the slightest score variations when striving for an Olympic medal.

As a result, it can be argued that performing only the elements with a high degree of difficulty is insufficient to improve one's ability to compete in RG. It also emphasizes the importance of expressing individual characteristics, the principle of uniqueness (Hashimoto et al., 2017), and the presentation of artistic components with minimal mistakes in choreographies.

Another notable result of the current study is that total average final scores of medalist gymnasts (ranging from 27.083 to 28.133 points) for all three apparatuses, except ribbon, were significantly higher than those of non-medalists (24.850–26.071 points). This outcome highlights the pivotal role of average total scores in hoop, ball, and clubs routines in determining medal status, with equally substantial effect sizes.

Additionally, both medalist and non-medalist gymnasts achieved higher scores in body, apparatus, and total club routines compared to all other apparatuses. Clubs, unique in rhythmic gymnastics as it is used in pairs and possesses a rigid structure (Jastrjemskaia & Titov, 1999), offers a platform for intricate, technically challenging, and diverse maneuvers. The distinct nature of clubs may account for the observed differences in scores.

However, when compared with the other apparatuses, it becomes apparent that the impact of all ribbon scores (all subcomponents and total score) on the final total final score is the least significant. Our results are consistent with the findings of a 2019 study that examined the WCh (Örs, 2021; Tatlibal et al., 2022), which consistently observed the lowest final scores in ribbon routines and the highest final scores in clubs.

Another significant finding in our study was that the total execution score for

ribbon was consistently the highest, regardless of medal status. This observation suggests that the execution of ribbon routines is prone to more frequent artistic and technical errors, possibly due to the unique structural features and the complexity of apparatus technique associated with the ribbon. Ribbon is the longest apparatus in rhythmic gymnastics, measuring 6 meters. Consequently, the demand to maintain the ribbon's movement throughout the routine while executing challenging elements can make its technical use particularly challenging.

Gymnasts may encounter difficulties when using this long and smooth apparatus, especially when performing elements like throws, catches, spirals, snakes, and boomerangs, which involve apparatus difficulty scores. Notably, in our study, we found that the apparatus difficulty scores of Olympic-level gymnasts were consistently lower for ribbon compared to the other three apparatuses, regardless of their medal status. This observation further supports our perspective.

Although this research has several strengths, it also has its limitations. Firstly, it's worth noting that the present study's findings were analyzed within the framework of the 2017–2021 Code of Points and exclusively within the context of the 2020 Tokyo Summer Olympics. Furthermore, the analysis solely relied on judging scores to evaluate the outcomes. As a recommendation for future studies, it may be beneficial to delve into the impact of choreography content, encompassing elements such as body challenges, rotational dynamics, and apparatus challenges, on the total score. This approach could aid in identifying key performance indicators that differentiate medalist and

non-medalist rhythmic gymnasts in individual senior Olympic finals.

CONCLUSIONS

To the best of our knowledge, this is the first study to analyze the contribution of each apparatus' (hoop, ball, clubs, and ribbon) score components to the overall score and to identify the key performance indicators that distinguish medalist from the top 10 non-medalist finalists in rhythmic gymnastics at the 2020 Olympic Games, Tokyo.

The findings of the present study indicate several factors that contribute to the success of Olympic medalist gymnasts:

- The gymnasts achieved the highest and lowest total scores with clubs and ribbon, respectively. However, it's notable that the ball apparatus, which encompasses five subcomponents related to difficulty, artistry, and execution (DA, D-Total, EA, E-Total, and Total Score), had the most significant influence in terms of securing an Olympic medal. In contrast, ribbon, with only one subcomponent (EA), had the least impact.

- When considering the total scores across all four apparatuses, it becomes evident that to achieve a substantial difference and secure an Olympic medal, the greatest impact is primarily attributed to the apparatus difficulty and artistic components. However, D-total and E-Total scores also make notable contributions to this outcome. It is worth noting that, for all apparatuses, the DB (Difficulty of Body) and ET (Execution Technique) scores displayed no significant effect on the final score. This finding, while intriguing, warrants careful consideration. It suggests that Olympic gymnasts, whether medalists or not, have a preference for incorporating

high-difficulty elements in their routines and perform similarly in terms of both apparatus and body elements. Nevertheless, it should be acknowledged that these results may vary based on error rates or differences in difficulty values.

This study provides reference values for key performance indicators and highlights the differences in choreographic components among the four apparatuses (hoop, ball, clubs, and ribbon) for individual senior rhythmic gymnastics finalists who either won or lost medals in the Olympics.

Based on these findings, coaches should prioritize choreography planning aimed at enhancing difficulty, particularly the apparatus difficulty score, while maintaining or even improving execution scores. Additionally, coaches should consider each gymnast's potential to incorporate artistic components with both body difficulties and apparatus challenges. This approach can elevate the initial scores of routines in a multidimensional manner.

While high scores in hoop, ball, and club apparatus routines play a crucial role in winning Olympic medals, coaches may consider devising new strategies for their gymnasts in the future by emphasizing technical excellence in ribbon routines.

In the future, coaches may have the opportunity to monitor the progress of gymnasts in choreography planning and Olympic Games preparation by analyzing the contribution of score components from Olympic gymnasts in each apparatus to the total score. Furthermore, the analysis of these score components can facilitate the optimization and personalization of gymnasts' training processes.

The findings of this study hold significance as they offer a fresh perspective on the ever-evolving

competition rules, which are regulated every four years by the FIG-RG-TC authorities.

Overall, more research is needed to confirm the current findings in different OGa with varying levels of rhythmic gymnast expertise.

Based on the results presented in the current study, it can be concluded that:

- The combined results of the four apparatuses are not equal to the overall result.
- The DA, D total, and EA scores in all four apparatuses play an important role in winning an Olympic medal.
- The influence of total score components (DB, DA, EA, and ET) on the final score varies depending on the specific apparatus.
- The ball is the most influential apparatus for securing Olympic medals, while ribbon has the least effect in this regard.

Coaches can use the current research findings in their planning of preparation strategies for gymnasts competing in all-around, team, and apparatus competitions.

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