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ABSTRACT
This study aims to analyze the type, number, and rotational directions of body rotation difficulties (BRD) preferred by gymnasts in their routines and which support foot/leg is in the BRD they perform. The relationships between the number of BRD in the routines and the competition scores of the gymnasts were also examined. The individual all-around final competition routines (N=72) of the elite senior gymnasts at the 39th Rhythmic Gymnastics (RG) World Championships held in 2022 were examined. RG evaluation rules were taken into account in the analysis of all BRD. The data were obtained by analyzing the routines recorded during the competitions. Descriptive statistical analyzes were made using the IBM SPSS 25.0 statistics program. In the ribbon, the mean values of the number of BRD used were higher, and the mean values of the difficulty and total scores were lower than the other apparatus. The mean value of the number of all BRD performed by the gymnasts in routines was determined as 26.2 ± 6.51. A significant correlation was found between the BRD numbers and scores of the gymnasts, mainly in the hoop and ball apparatus p<5%. *Illusion* (forward), *Fouette* (leg stretched horizontally), and Split back without help (trunk horizontal) were preferred more by gymnasts in all routines. The gymnasts generally exhibited rightward rotation direction preferences and used the right support foot/leg in most of their preferred BRD. Bilateral or supportive exercises should be included to prevent the harmful effects of unilateral loading while creating perfect movements with repetitions.

Keywords: rhythmic gymnastics, individual routines, body rotation difficulties, rotational direction preferences, support foot, video analysis

INTRODUCTION

In rhythmic gymnastics (RG), the movements performed are versatile in terms of their use of plane, axis, and level. These movements are exhibited in perfect harmony with the music. Meticulously prepared competition compositions attract the attention of children of all ages.

In RG, body difficulties, apparatus difficulties, dynamic elements with rotation, dance steps, and body waves are typical components of a competition routine. Body difficulties include jumps/leaps, balances, and rotations (Body:B, Rotation:R, Difficulties:D/BRD) (FIG, RG-CoP, 2022-2024). Rotation patterns and numbers, together with the apparatus's unique movements, arouse the audience's interest the strength, flexibility, and balance skills contribute to good BRD performance. Gaining speed with a good preparation position, controlled swinging of the arms and legs, fixing the body position/shape and maintaining the vertical axis (in balance) are essential aspects of BRD. It has been stated that core strength is fundamental in rotation (Gateva, 2013; Han, 2020), and if the core muscles are not strong enough, once the movement has started, the muscle direction might change or disperse, causing the body axis to become unstable or tilt (Han, 2020).

In the BRD tables (with base values ranging from 0.10 to 0.70 points) in RG-Code of Points (CoP), there are a total of 59 different BRD with variations of some rotations. These BRD can be performed on the toes in relevé position (on the toes) or flat foot, on one foot/leg or both feet/legs, or on other/different body parts (knee, chest, etc.). Rotations can be performed in two ways about the rotational direction of the non-support leg: *en dehors* (outwards) and *en dedans* (inwards). Rotations other than BRD are frequently used in pre-acrobatic movements and vertical rotations. Increasing the number of turns above the base value or with combined difficulties (combining the two body difficulties), the value of the BRD can be increased (FIG, RG-CoP, 2022-2024), Thereby (positively) affecting the difficulty score of the routine and, as a consequence, the total score.

Lateralized behavior can be seen in many sports branches. For example, sports such as gymnastics, figure skating or platform diving skills incorporate rotations about one or more body axes, and athletes usually prefer one or the other rotation direction (Heinen, Jeraj, Vinken, & Velentzas, 2012; Heinen, Bermeitinger, & von Laßberg, 2016). Is this a "natural" phenomenon or does training influence it? The relationships between lateral preference and

rotation preference in gymnastics were also investigated (Heinen, Vinken, & Velentzas, 2010). Even if some practitioners state that gymnasts should be encouraged to practice both directions, a constant "overuse" of one direction could potentially contribute to the overuse problem. Therefore, gymnasts should be encouraged to practice both rotation directions. Even though the development of a preferred rotation direction should be supported the gymnast should be able to turn to the other side as well, at least in training (Bessi, Hofmann, von Laßberg, & Heinen, 2016).

Poor load management is a significant risk factor for injuries (Soligard et al. 2016). Grueva-Pancheva has stated that the ankle and foot complex is a body segment that undergoes a high load in rhythmic gymnasts, additionaly, constant standing on toes and repetitive movements (like engaging in a relevé position, performing pirouettes, and jumping), apply acute stress on soft tissues/passive structures in the area. Due to poor proprioception, incorrect performance techniques of these rigorous activities repeated many times daily by a gymnast can lead to overuse injuries (Grueva-Pancheva, 2022). If element repetition is not balanced for excellent skills or inadequate recovery time is allowed, the risk of overuse injuries rises (Tayne, Bejarano-Pineda, & Hutchinson, 2021). Overuse injuries have been found to be 76.7% (Gulati, Rychlik, Wild, & LaBella, 2022). In RG, injuries caused by pirouette have been observed in the ankle, knee, and back regions and possible causes have been specified (Oltean, Rusu, Copoiu, & Călin, 2017). Pirouettes have been determined to be the most frequent mechanism of injury in professional dancers, accounting for 67.9% of injuries (Costa, Ferreira, Orsini, Silva, & Felicio, 2016). The extreme positions adopted when performed on relevé can lead to repetitive strain injuries of the foot and ankle. The ankle joint is the most loaded joint during pirouettes, and these high values of joint reaction forces may explain the causes of numerous injuries (Błażkiewicz, 2021).

Muscle-tendon unit injuries have been reported in 85% of gymnasts (Zetaruk et al., 2006). Among rhythmic gymnasts, these were most frequently located in the lower extremities; specifically, the foot, ankle, and knee, and the most frequent injury type were strains and sprains (Cupisti, et. all 2007; Gulati, Rychlik, Wild, & LaBella, 2022; Tayne, Bejarano-Pineda, & Hutchinson, 2021). Lower extremity injury rates have been found to be 81% (Kutlay, Kocahan, Arpınar, & Nalçakan, 2001). The regional distribution rates of injuries have been reported as 29.8% for the ankle, 21.1% for the knee, 19.3% for the Achilles tendon/heel, and 15.8% for the foot and toes (Kutlay, Demirbüken, Özyürek & Angın, 2008). These injury rates were determined in another study as 23.9% for the back, 17.3 for the knee, 15.2% for the leg (tibia), 15.2% for the foot and 10.9% for the ankle (Hutchinson, 1999). Cupisti et al. determined the rate of foot and ankle injury as 38.9% (Cupisti et al. 2007). Although these studies were conducted in different years, they draw attention to preventing foot and ankle injuries. With the findings and perspectives of these studies, the importance of protective exercises that support joint stability is increasing. Coaches should consider these issues while setting goals for their gymnasts.

Another issue that can be caused by unilateral loading is asymmetries. Although it is stated that there is no strong evidence for the relationship between lower-limb functional asymmetry and sports injuries (Helme, Tee, Emmonds, & Low, 2021), attention has been drawn to the symmetry and methods of the movements so that the athletes can continue their careers in a healthy way (Starosta, 2018). Asymmetrical impact forces, joint torques, and muscle forces may lead to further bilateral changes in the biomechanics of the movement, which may, in turn, become detrimental to the athlete (Parrington & Ball, 2016). It has been stated that repetitive rehearsals on the preferred leg can strengthen the effect of side dominance in experienced dancers (Lin, Su, Wu, & Lin, 2013). The emergence of inter-limb asymmetries should be regarded in the context of sport-specific movements/tasks. Attention has been drawn to the evaluation of the effect of exercise-induced fatigue on sport-specific tasks and the load-dependent inter-limb asymmetries related to the risk of non-contact injury with tests (Heil, Loffing, & Büsch, 2020). A study on this subject determined that lower limb asymmetries were related to lateral preference and rhythmic gymnastics training (Frutuoso, Diefenthaeler, Vaz, & Freitas, 2016).

Creative movements have an important place in RG. Competition rules are updated according to these creative ideas while keeping the philosophy and strategy of the sports branch. The CoP is determined by the FIG and is updated every Olympic cycle. In the senior category, a total of 3-9 body difficulties including at least one jump/leap, one balance, and one rotation in each routine, are required, and gymnasts can use their body difficulties so that they can perform well more than once. If the gymnasts' rotations are better than their other difficulties they can do more than one body rotation difficulty in a routine (FIG, RG-CoP, 2022-2024). As for the types of competition, in RG World Championships (Individual competitions) include Qualifications, Individual All-Around Finals and Apparatus Finals. The qualification for the All-Around Final made by adding the three best scores obtained in the Qualification. The 18 best gymnasts from Qualifications participate in the All-Around Final (max. 2 per National Federation). The program consists of 4 exercises/routines with the four prescribed apparatuses, and the ranking is made by adding the four scores obtained with the four apparatuses (FIG-2022 Technical Regulations RG).

The coaches should create a broad base for the gymnast's physical preparation (Jastrjembskaia, & Titov, 1999). Although gymnasts generally execute their rotational preferences according to the characteristics of the apparatus or composition, they prefer the side they can perform without mistakes. Therefore we wanted to analyze the type,

number, and rotational directions of BRD preferred by gymnasts in their routines, and which support leg is in the BRD they perform. Additionally, the relationships between the number of BRD in the routines and the competition scores of the gymnasts were also examined. In this cross-sectional study, we hypothesized that gymnasts use one side more in their BRD.

MATERIALS AND METHODS

Participants: The All-Around Final Competition routines (N = 72) (hoop, ball, clubs and ribbon) of the individual elite senior rhythmic gymnasts (N = 18) (19.7 ± 2.9 years old) at the 39th Rhythmic Gymnastics (RG) World Championships (WCh) held in 2022 were examined.

Research Design: The type, number, and rotational directions of body rotation difficulties (BRD) preferred by gymnasts in their routines, and which support leg is in the BRD they perform were analyzed. The number of uses and percentage of each difficulty were calculated. The relationships between the number of BRD in the routines and the competition scores of the gymnasts were also examined. The percentage values of the turning preferences and the support foot/leg used in the turns, which were performed on all apparatuses, were also examined.

RG evaluation rules (FIG, RG-CoP, 2022-2024) were considered in the analysis of all BRD (with base values ranging from 0.10 to 0.70 points). BRD [without major execution technique mistakes (such as loss of apparatus, loss of balance with fall)] with a minimum base rotation of 180° and 360° were considered. Rotations were not evaluated (as a judge); only which rotation the gymnasts preferred and how they used it were examined. The BRD used in other composition components of the composition was included in the study (such as apparatus difficulties, and dynamic elements with rotation and dance steps). The combined BRD made up of the two difficulties was evaluated separately. The study did not include other rotations (pre-acrobatic elements, vertical rotations) that were part of the routine.

The data were obtained by analyzing the routines recorded during the competitions. The analyses of all competition routines were evaluated simultaneously with two RG judges (international and national level). It was recorded with the symbolic writing used in RG (FIG, RG-CoP, 2022-2024). When there was a difference in analysis among the judges, the video recording of the competition routine was slowed down, and movements were compared and rechecked. In addition, the relationship between the number of all BRD used in each routine and the gymnasts' scores [(body difficulty score (BDS), apparatus difficulty score (DAS), difficulty score (DS), total score (TS)] was examined. The individual routines' official competition scores were reached from the results book of the 39th RG-WCh published on the FIG's official web page ("Gymnastics events").

Statistical Analysis: Descriptive statistical analyzes were made using the IBM SPSS 25.0 statistics program. Values were presented as frequencies, percentages (%) and Mean ± Standard Deviation. To calculate the percentage of rotations most preferred by gymnasts, BRD used more than once in the routine were considered to be used once. Numbers are given next to the BRD figures used in Table 2. In the second (performed on two legs) and twenty-fifth (performed on one part of the body) difficulties listed in Table 2, only the preferred rotational directions of the gymnasts were evaluated. The relationship between variables was calculated with the Pearson Correlation coefficient (r). The significance level was defined as $p<5\%$.

RESULTS

The mean values of all BRD numbers used in routines were seen the most in the ribbon and the least in the ball. The mean value of the number of all rotations performed by the all gymnasts on the four apparatus was determined as 26.2 ± 6.5 (Table 1). The mean difficulty body scores (DBS) were close to each other in all routines, with the highest value in the hoop and the lowest value in the ribbon. The highest value was observed in the ball and the lowest in the ribbon in the mean values of Difficulty Apparatus scores (DAS). The lowest values in the mean values of DS and TS scores were observed in the ribbon (Table 1).

Table 1. The number of all body rotation difficulties performed and DBS, DAS, DS and TS competition scores in all routines

N=72	Hoop (n=18) x̄ and SD	Ball (n=18) x̄ and SD	Clubs (n=18) x̄ and SD	Ribbon (n=18) x̄ and SD	
TRN	-	-	-	-	**26.2 ± 6.5**
BRDN	6.8 ± 2.2	5.7 ± 1.7	6.4 ± 1.9	7.3 ± 1.9	-
DBS	9.6 ± 0.8	8.8 ± 0.9	9.5 ± 0.8	8.7 ± 0.8	-
DAS	5.1 ± 0.6	5.7 ± 0.5	4.8 ± 0.5	4.2 ± 0.5	-
DS	14.7 ± 1.1	14.5 ± 1.9	14.3 ±1.1	12.9 ± 1.1	-
TS	30.9 ± 1.7	30.9 ± 1.5	30.6 ± 1.6	28.8 ± 1.8	-

N;Total number of routine, **n;**Number of routine, **x̄ and SD;**Mean and Standard Deviation, **TRN**;Total rotation numbers (the number of BRD a gymnast uses in all her routines), **BRDN;**Number of all body rotation difficulties, **DBS;**Difficulty body score, **DAS;**Difficulty apparatus score, **DS;**Difficulty score, **TS**;Total score.

Table 2. Gymnasts' rotational direction preferences and support leg preferences (%) in used BDR

N=72 BRD		Hoop n=18	Ball n=18	Clubs n=18	Ribbon n=18	BRD		Hoop n=18	Ball n=18	Clubs n=18	Ribbon n=18
1.	R	16.7	16.7	22.2	22.2	14.	R	38.9	38.9	38.9	38.9
	L	11.1	11.1	33.3	16.7		L	-	-	-	-
	SR	22.2	16.7	33.3	22.2		SR	38.9	38.9	38.9	38.9
	SL	5.6	11.1	22.2	16.7		SL	-	-	-	-
2.	R	-	-	16.7	-	15.	R	16.7	11.1	11.1	16.7
	L	22.2	22.2	5.6	22.2		L	-	-	-	-
3.	R	11.1	11.1	27.8	16.7		SR	16.7	11.1	11.1	16.7
	L	16.7	16.7	5.6	22.2		SL	22.2	-	-	-
	SR	11.1	11.1	33.3	22.2	16	R	22.2	27.8	27.8	27.8
	SL	16.7	16.7	-	16.7		L	5.6	5.6	5.6	5.6
4.	R	-	-	-	27.8		SR	22.2	27.8	27.8	27.8
	L	-	-	-	-		SL	5.6	5.6	5.6	5.6
	SR	-	-	-	17.7	17.	R	11.1	22.2	11.1	11.1
	SL	-	-	-	11.1		L	-	-	-	-
5.	R	-	-	-	-		SR	11.1	22.2	11.1	11.1
	L	5.6	5.6	5.6	5.6		SL	-	-	-	-
	SR	-	-	-	-	18.	R	-	-	-	-
	SL	5.6	5.6	5.6	5.6		L	38.9	27.8	22.2	22.2
6.	R	-	-	-	-		SR	-	-	-	5.6
	L	-	-	5.6	-		SL	38.9	27.8	22.2	16.7
	SR	-	-	-	-	19.	R	-	-	-	-
	SL	-	-	5.6	-		L	-	16.7	11.1	11.1
7.	R	-	-	-	-		SR	-	-	-	-
	L	5.6	-	-	-		SL	-	16.7	11.1	11.1
	SR	-	-	-	-	20	R	-	-	-	5.6
	SL	5.6	-	-	-		L	-	-	-	-
8.	R	-	-	5.6	5.6		SR	-	-	-	-
	L	-	-	-	-		SL	-	-	-	5.6
	SR	-	-	5.6	5.6	21.	R	72.2	72.2	88.9	77.8
	SL	-	-	-	-		L	11.1	11.1	-	11.1
9.	R	11.1	22.2	16.7	16.7		SR	11.1	11.1	-	11.1
	L	22.2	5.6	22.2	22.2		SL	72.2	72.2	88.9	77.8
	SR	-	16.7	11.1	11.1	22.	R	-	-	5.6	-
	SL	33.3	11.1	27.8	27.8		L	88.9	94.4	88.9	94.4
10.	R	5.6	5.6	5.6	5.6		SR	88.9	94.4	88.9	94.4
	L	-	5.6	-	-		SL	-	-	5.6	-
	SR	5.6	5.6	5.6	5.6	23.	R	-	-	-	-
	SL	-	5.6	-	-		L	-	-	-	5.6
11.	R	-	-	-	-		SR	-	-	-	5.6
	L	-	5.6	5.6	-		SL	-	-	-	-
	SR	-	-	-	-	24.	R	22.2	22.2	11.1	11.1
	SL	-	5.6	5.6	-		L	-	-	5.6	-

12. 	R	5.6	5.6	5.6	5.6		SR	22.2	22.2	11.1	11.1
	L	-	-	-	-		SL	-	-	5.6	-
	SR	5.6	5.6	5.6	5.6	25. 	R	-	-	-	-
	SL	-	-	-	-		L	-	-	-	5.6
13. 	R	-	-	-	5.6						
	L	-	-	-	-						
	SR	-	-	-	5.6						
	SL	-	-	-	-						

N; Total number of routine, **n;** Number of routine, **BRD;** Body rotation difficulties, **R;** Right, **L;** Left, **SR**; Right support foot/leg **SL;** Left support foot/leg. The BRD figures and their explanations (specified below) in the table are as specified in the CoP (FIG, RG-CoP, 2022-2024). 1.*Passé*; 2.Spiral turn on both legs; 3.Spiral turn partial wave on one leg; 4.Free leg horizontal forward; 5.Front split with help; 6.Front split without help; 7.Elkatib; 8.Side split with help, trunk horizontal; 9.Side split without help, trunk horizontal; 10.Raffaeli; 11.Trubnikova; 12.Arabesque; 13. Back split with help; 14.Split back without help, trunk horizontal; 15.Split back without help trunk horizontal with ring; 16.Attitude; 17.Ring with help; 18.Kabaeva standing position; 19.Kabaeva, seated position; 20.*Fouetté Passé*; 21.Fouetté with leg stretched; 22.*Illusion* trunk bend forward/side, at horizontal or below; 23.*Illusion* trunk bend backward, at horizontal or below; 24.*Penché* on flat foot; 25.Ralenkova.

In all routines, rotational direction preferences and support foot/leg preferences (right (R) and left (L) side) were determined respectively as in 22 (between 88.9% and 94.4% towards the L; support foot is R), in 21 (between 72.2% and 88.9% towards the R; support foot is L), in 14 (38.9% towards the R; support foot is R), in 18 (between 22.2% and 38.9% towards the L; between 16.7% and 38.9% support foot is L), in 1 (between 11.1% and 33.3% towards the L; between 16.7% and 33.3% support foot is R), in 3 (between 11.1% and 27.8 % towards the R, between 11.1% and 33.3% support foot is R), in 16 (between 22.2% and 27.8 % towards the R, support foot is R) in the most used BRD. The rotation preferences and support foot preferences of the other BRD varied between 5.6% and 22.2% respectively. BRD performed in both directions of rotation and also on both the right and the left foot were observed the most in 1, 3, and 9 (Table 2).

Table 3. Frequencies and percentages of each BRD used according to rotation preferences and support foot/leg preferences in all routines (N=72)

BRD		Num	%	BRD		Num	%	BRD		Num	%	BRD		Num	%
1.	R	14	19.4	8.	R	2	2.8	14.	R	28	38.9	20.	R	1	1.4
	L	13	18.1		L	-	-		L	-	-		L	-	-
	SR	17	23.6		SR	2	2.8		SR	28	38.9		SR	-	-
	SL	10	13.9		SL	-	-		SL	-	-		SL	1	1.4
2.	R	3	4.2	9.	R	12	16.7	15.	R	10	13.9	21.	R	56	77.8
	L	13	18.1		L	13	18.1		L	-	-		L	6	8.3
3.	R	12	16.7		SR	7	9.7		SR	10	13.9		SR	6	8.3
	L	11	15.3		SL	18	25		SL	-	-		SL	56	77.8
	SR	14	19.4	10.	R	4	5.6	16.	R	19	26.4	22.	R	1	1.4
	SL	9	12.5		L	1	1.4		L	4	5.6		L	66	91.7
4.	R	5	6.9		SR	4	5.6		SR	19	26.9		SR	66	91.7
	L	-	-		SL	1	1.4		SL	4	5.6		SL	1	1.4
	SR	3	4.2	11.	R	-	-	17.	R	10	13.9	23.	R	-	-
	SL	2	2.8		L	2	2.8		L	-	-		L	1	1.4
5.	R	-	-		SR	-	-		SR	10	13.9		SR	1	1.4
	L	4	5.6		SL	2	2.8		SL	-	-		SL	-	-
	SR	-	-	12.	R	4	5.6	18.	R	-	-	24.	R	12	16.7
	SL	4	5.6		L	-	-		L	20	27.8		L	1	1.4
6.	R	-	-		SR	4	5.6		SR	1	1.4		SR	12	16.7
	L	1	1.4		SL	-	-		SL	19	26.4		SL	1	1.4
	SR	-	-	13.	R	1	1.4	19.	R	-	-	25.	R	-	-
	SL	1	1.4		L	-	-		L	7	9.7		L	1	1.4
7.	R	-	-		SR	1	1.4		SR	-	-				
	L	1	1.4		SL	-	-		SL	7	9.7				
	SR	-	-												
	SL	1	1.4												

N;Total number of routine, **BRD;** Body rotation difficulties, **Num;** Number of BRD, **R;** Right, **L;** Left, **SR**; Right support foot/leg **SL;**Left support foot/leg. The numbers of BRD figures specified in Table 2 also apply to Table 3

It was observed that BRD numbered 22, 21, 14, 16, 18 had the highest numerical and percentage values (Table 3).

Table 4. Frequencies and percentages of BRD in all apparatus

N=72	Hoop BRD Number	%	Ball BRD Number	%	Clubs BRD Number	%	Ribbon BRD Number	%	All Apparatus BRD Total Number	%
R	42	50.6	46	52.9	52	57.8	53	54.6	**193**	**54.1**
L	41	49.4	41	47.1	38	42.2	44	45.4	**164**	**45.9**
SR	46	58.2	51	61.5	50	58.1	57	62.0	**204**	**60.0**
SL	33	41.8	32	38.5	36	41.9	35	38.0	**136**	**40.0**

N;Total number of routine, **BRD;** Body rotation difficulties, **R;** right, **L;** left, **SR**; right support foot/leg **SL;** left support foot/leg

Considering all the BRD performed, 193 (54.1%) were applied to the right side and 164 (45.9%) were applied to the left side. In addition, the right support foot/leg was used in 204 (60%) of these BRDs and the left support foot/leg was used in 136 (40%) of them (Table 4).

Table 5. Relationships between gymnasts' BRD numbers and the competition scores in all routines

N=72		Hoop	Ball	Clubs	Ribbon
TS	Pearson Correlation	0.566*	0.492*	0.406	0.114
	Significant Value	0.014	0.038	0.094	0.651
DS	Pearson Correlation	0.538*	0.489*	0.377	0.185
	Significant Value	0.021	0.039	0.123	0.462
DBS	Pearson Correlation	0,328	0.511*	0.481*	0.139
	Significant Value	0.184	0.030	0.043	0.583
DAS	Pearson Correlation	0.601**	0.182	0.035	0.190
	Significant Value	0.008	0.471	0.891	0.450

N;Total number of routine, **TS;**Total Score, **DS;**Difficulty score, **DBS;**Difficulty Body Score, **DAS;**Difficulty Apparatus Score

Significant correlations were observed between BRD numbers and TS (r = 0.566, p = .014), DS (r = 0.538 p = .021), DAS (r = 0.601, p = .008) in the hoop. Significant correlations were observed between BRD numbers and TS (r = 0.492, p = .038), DS (r = 0.489, p = .039), DBS (r = 0.511, p = .030) in the ball. Significant correlation was observed BRD numbers and DBS (r = 0.481, p = .043) in the clubs (Table 5).

DISCUSSION

What constitutes an athlete's rotational preference? These issues have been discussed in the literature, theoretically and empirically (Heinen, Bermeitinger, & von Laßberg, 2016). We thought these issues might also be important in RG, so we wanted to carry out this analysis study. This study aims to analyze the type, number, and rotational directions of body rotation difficulties (BRD) preferred by gymnasts in their routines and which support foot/leg is in the BRD they perform. Additionally, the relationships between the number of BRD in the routines and the gymnast' scores were also examined.

RG, a sport practiced with aesthetic and technical movements (body/apparatus) accompanied by music, requires high-level motor control (Jastrjembskaia & Titov, 1999). Elite gymnasts are the ones who best reflect the culture of movement according to the rules, and they perform their movements perfectly (body/apparatus techniques). Therefore, we wanted to examine the routines of these gymnasts. The preferences of BRD are determined by the coach based on the gymnast's physical preparation, ability, skills, and motor development and according to the designed movements or the characteristics of the apparatus. And also some admirable popular movements are adopted and practiced by many gymnasts. For these reasons, movement tendencies may differ. Our study indicated

that gymnasts performed only 25 (42.3%) of the BRD in RG-CoP 2022-2024. When the preferred rotation types according to the apparatus were examined, it was seen that 16 (27.1%) rotations were used in the hoop, 17 (28.8%) in the ball, 20 (33.8%) in the clubs, and 22 (37.2%) in the ribbon (Table 2). Higher diversity of use was observed in the ribbon.

A training volume has been determined between 39.5 ± 7.0 and 41.4 ± 5.9 hours/week in senior elite gymnasts (Ávila-Carvalho, Klentroub, Palomero, & Lebre, 2013). In the training of the competition period, the gymnasts have been stated to perform routine repetitions 16-30 times in each training with 2 or 4 apparatuses per day (Jastrjembskaia & Titov, 1999). Furthermore, gymnasts can sometimes use the body difficulty they perform well in more than one routine. This leads to more repetitions of a particular body difficulty. In our study, the number of all BRD performed by the gymnasts (four apparatus) was determined as 26.2 ± 6.5 (Table 1). Repeating these difficulties in preparation and competition periods, in podium trainings and competitions can stress the musculoskeletal system that performs the movement. It has been explained that an important injury risk factor is the number of repetitions associated with training and competition, as well as the timing and intensity of that loading (Tayne, Bejarano-Pineda, & Hutchinson, 2021).

In our study, when the mean values of the BRD numbers used in the routines were examined, it was seen that the most were in ribbon and the least were in ball (Table 1). Apparatuses are divided into two rigid (hoop, ball, and clubs) and soft (ribbon and rope) in terms of their structural features (Jastrejevskaya, 1995). The length of the ribbon for the senior category is 6 meters. Since the ribbon is a soft and long apparatus, it is difficult to control in movements. Speed gained in rotations can positively affect the shapes (e.g. circles) of the ribbon fabric in space. Therefore, more rotations may have been used in the ribbon. Additionally, in the old CoP, BRD were the basic body element for the ribbon. These may be reasons why BRD is used more in ribbon.

In our study, the mean Difficulty body scores (DBS) were close to each other in all routines, with the highest value in the hoop and the lowest value in the ribbon. The highest value was observed in the ball and the lowest in the ribbon in the mean values of Difficulty apparatus scores (DAS). The lowest value in the mean values of DS and TS scores was observed in the ribbon (Table 1). Alteration of the pattern formed by the ribbon, snakes and spirals insufficiently tight not the same height, amplitude, wrappings, knot, the end of the ribbon staying on the floor involuntarily during the performance of pattern etc., are execution penalties for ribbon apparatus (FIG, RG-CoP, 2022-2024). For body and apparatus difficulties to be valid, the apparatus handling must be performed without mistake. For these reasons, the scores in the ribbon apparatus may be lower.

In this study, in all routines, in the most preferred BRD (numbered 22, 21, 14, 18, 1, 3 and 16), rotational preferences were found between 11.1% and 94.4%, and it was observed that the right support foot was used more in the same BRD. The rotation preferences and support leg/leg preferences of the other BRD varied between 5.6% and 22.2%. BRD performed in both directions of rotation and also on the right and the left foot were observed the most in 1, 3, and 9 (Table 2). Gymnasts usually exhibited a particular preference for their movements. The results of this study support our hypothesis. The gymnasts turn to the right side in their preferred BRD, and use the right support foot/leg more in their rotations.

Considering all of the apparatus, we wondered about each difficulty's frequency and percentage of use. Since some difficulties (i.e. *Passé, Illusion*) are used more than once in a routine, we assumed that a gymnast used this difficulty once when calculating the percentage of usage. It was observed that BRD numbered 22, 21, 14, 16, and 18 had the highest numerical and percentage values. When these rotations were examined, it was determined that the right side turn and the right support leg was used more (Table 3). Similar results were observed when we evaluated it from this point of view. Considering all the BRD performed (total number of BRD performed by the gymnast in four apparatus), 193 (54.1%) were applied to the right side and 164 (45.9%) were applied to the left side. In addition, the right support foot/leg was used in 204 (60%) of these BRDs and the left support foot/leg was used in 136 (40%) of them (Table 4). Although there is not a big difference in the preference of both sides when all the rotations made are taken into account, it is observed that these values are higher when the most preferred rotations are considered. In the routine, we assumed that the gymnast had used a particular BRD once (for frequency and percentage values). For example, considering the athletes who use the "*Illusion*" (Number 22) (Table 2) difficulty more than once in their routine, the use of support feet/legs will increase even more.

There may be some interaction between gymnasts in preferred movements. However, the preferred body difficulties for composition reflect the technical value of a routines and the gymnast's technical preparation. For example, in a study on the analysis of individual competitive forms (112 routines, N = 28), it was observed that 36% of the BRD specified in the FIG, RG-CoP (2005-2008) were used. Additionally the BRD most frequently used by gymnasts has been determined as "*Fouette* (Passé)" in the rope and clubs, "*Attitude*" in the ball, and "Split forward with support" in the ribbon (Kutlay, Yardımcı, 2007). In another study, at the 2013 WCh, the more commonly used difficulties were rotation "*Attitude*" rotation with "Free leg in the ring in back with help" "rotation

in *Penché*" (Leandro, 2016). In this study, *Illusion* (forward), *Fouette* (leg stretched horizontally), and Split back without help (trunk horizontal) were preferred more by gymnasts in all routines.

Pedagogical effects (training), habits, structural features of the apparatus, choreographic requirements, and tendencies to increase the difficulty score can affect the preferences of lower limb in BRD. In our study, gymnasts mostly showed a tendency to use the right foot/leg in BRD. It has been explain that differences in technical skill between the two sides of the body are disadvantageous because athletes may later become dependent on preferred or dominant extremities (Parrington, & Ball, 2016). Multiple repetitions with the dominant extremity can lead to asymmetries in high-level performance processes. Some sport-specific postural problems may develop due to asymmetrical loading (Radaš, & Bobić, 2011). Our results may prompt reflection on the BRD designed in skill acquisition of gymnasts.

The need for ambidexterity should be considered in the planning of training programs (Bozanic, & Miletic, 2011). The routine length in RG is 1.30 seconds. In order to achieve a good D-score in this short time, high-value difficulties may be preferred. Some gymnasts perform better in jumps/leaps, balances or rotations. Although the use of one side in the routine is tried to be partially balanced with other body difficulties, each movement difficulty (jumps/leaps, balances, rotations) group has different motor skill features that stand out. Our study supports the idea that coaches need to balance these body difficulties and other components of composition very well to avoid the adverse effects of repetitions while creating perfect movements.

DS is the sum of DBS and DAS, and TS is the sum of DS, artistic and execution scores. Both the artistic and execution scores are the remaining scores after deducting the penalties for composition, body, and apparatus technique faults (FIG, RG-CoP, 2022-2024). In the routines of elite gymnasts, DS may be higher than artistic or execution scores and has a more significant impact on TS. With this point of view, we wanted to examine the relationship between the BRD numbers in the gymnasts' routines and the competition scores ("Gymnastics events"). Significant correlations were observed between BRD numbers and TS, DS, and DAS in the hoop. Significant correlations were observed between BRD numbers and TS, DS, and DBS in the ball. Significant correlation was observed between BRD numbers and DBS in the clubs, but significant correlation were not observed between BRD numbers and these scores in ribbon (Table 5). It is thought that the BRD numbers in the hoop and ball apparatus may have affected the gymnasts' scores more than the other apparatus. Although BRD was used more in the ribbon than other apparatus, it may not have been reflected in the athlete's scores due to the difficult control of the apparatus. The body and apparatus difficulties may not have been counted due to execution faults.

Our study has some limitations. First, our sample of eighteen elite senior rhythmic gymnasts was a small sample. If Competition I (Qualifications) (where all gymnasts compete) had been analyzed, the results might have been different. Whether there is a relationship between lateral preference (handedness and footedness) and rotational preference would have enriched our study, but we could not do this, perhaps it can be done in another study in the future. Second, kinematic analyzes are needed to recognize better the mechanical loads on the musculoskeletal system of a gymnast performing rotations. However, we hope that the results of our study will provide insights for the training patterns and choreographic elements/designs. In the future, investigating different movement difficulties will provide more information for the development of RG. As the third, we analyzed only BRD, however, gymnasts also practice pre-acrobatic elements (thirteen, and its variations) and vertical rotations (five, and its variations) (specified in Cop) in their routines. Apart from BRD, other rotations performed in routines may be the subject of another study in the future.

Each gymnast's performance goals, different training styles, training regimes, coaching strategies and the intensity, content and frequency of training can be different. Regular athlete monitoring is fundamental to ensure appropriate and therapeutic levels of external and internal loads. Regular athlete monitoring is fundamental to ensure appropriate and therapeutic levels of external and internal loads and thus to maximize performance and minimize the risk of injury (Soligard et al. 2016). The importance of assessing the effect of exercise-induced fatigue on sport-specific tasks and the load-dependent inter-limb asymmetries related to the risk of non-contact injury by tests was emphasized. An analysis of the changes during load reveals possible differences, and helps detect the reasons and mechanisms underlying inter-limb asymmetries and asymmetrical loading (Heil, 2022). The results of this study contributed to a better understanding of the characteristics of BRD in high-level competitive routines within the context of competition rules applied in this Olympic cycle. It has also been tried to draw attention to one of the mechanisms of injury that may occur in gymnasts.

CONCLUSION

Analysis studies contribute to the improvement of sportive performance, and also give information to design targeted strategies for injury prevention. This study may offer a different perspective on reducing unilateral loads

in rotations. The information from these results may be useful to RG coaches in terms of understanding how to design routines for rotation difficulties. The gymnasts generally exhibited rightward rotation direction preferences and used the right support foot/leg in most of their preferred BRD. Bilateral or supportive exercises should be included while developing excellent skills and compositions. The balanced use of body segments in the compositions is essential for a healthy performance development.

Author Contributions
All authors have made substantial contributions to the conception and design of the study. EK and PT undertook literature search, acquisition of data, and analysis. All authors contributed to the interpretation of the results.

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