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The Rotations and Rotation Directions Preferred by Elite Rhythmic Gymnasts in "Dynamic Elements with Rotation"

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Abstract

Aim: The purpose of the study is to analyze the rotation types, numbers, frequencies, and preferred rotation directions in "dynamic elements with rotation" in all routines of rhythmic gymnasts.

Methods: The gymnasts' individual All-around Final competition routines (n = 96, 19.8±3.3 years old) at the 39th European Championships in Rhythmic Gymnastics in 2023 were examined. The data were derived from an analysis of the routines documented throughout the competitions. In the analysis the Rhythmic Gymnastics evaluation rules were considered. The IBM SPSS 25.0 statistics program was used for all descriptive analyses.

Results: The number of rotation types was 8.3±0.95. The highest number of rotations was found in the hoop routines. Considering each rotation, executed the number of rotations was determined as 14.4±1.6. The total number of body rotations performed by all gymnasts on four routines was observed as 57.5 ± 6.5. In the pre-acrobatic elements, rotation no 1, 2, 3, 4 and in the vertical rotations rotation no 1, 2, 4 were mostly preferred. The Illusion was the most preferred in all rotational movements. In dynamic elements with rotation, gymnasts preferred the right direction approximately twice as much as the left direction.

Conclusion: Excessive repetitions to perform movements without mistakes with perfect timing and correct body technique may cause loads, micro-traumas, muscle damage, and asymmetries on the body. While creating the choreographic designs of the composition, protective measures can be taken by paying attention to the load balance on both sides of the body.

Keywords

Dynamic elements with rotation, Rotation direction preferences, Individual routines, Performance analysis, Rhythmic gymnastics.

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"Rotasyonlu Dinamik Elementler"de Elit Ritmik Cimnastikçilerin Tercih Ettikleri Rotasyonlar ve Rotasyon Yönleri

Özet

Amaç: Bu çalışmada ritmik cimnastikçilerin tüm rutinlerinde "rotasyonlu dinamik elemenler" içindeki rotasyon çeşitleri, sayıları, sıklıkları ve tercih edilen rotasyon yönleri analiz edildi.

Yöntem: 2023 yılında düzenlenen 39. Avrupa Ritmik Cimnastik Şampiyonası'nda cimnastikçilerin (n = 96, 19,8±3,3 yaş) bireysel All-around Final yarışma rutinleri incelenmiştir. Veriler yarışmalar sırasında kaydedilen rutinlerin analiz edilmesiyle elde edilmiştir. Analizlerde Ritmik Cimnastik değerlendirme kuralları dikkate alınmıştır. Tanımlayıcı bütün istatistiksel analizler IBM SPSS 25.0 istatistik programı kullanılarak yapılmıştır.

Bulgular: Tüm rotasyonlu dinamik elemenlerde; rotasyon çeşidi sayısı, 8,3±0,95 olarak saptanmıştır. En yüksek rotasyon sayısı çember rutinlerinde gözlenmiştir. Her bir rotasyon dikkate alındığında, gerçekleştirilen rotasyon sayısı 14,4±1,6 olarak belirlenmiştir. Tüm cimnastikçilerin dört rutinde gerçekleştirdiği toplam vücut rotasyon sayısı 57,5±6,5 olarak gözlenmiştir. Preakrobatik elementlerden 1, 2, 3 ve 4 numaralı ve dikey rotasyonlardan 1, 2 ve 4 numaralı rotasyonlar en fazla tercih edilen rotasyonlar olarak belirlenmiştir. İllüzyon hareketi tüm rotasyon elementlerinde en çok tercih edilen hareket olmuştur. Cimnastikçiler rotasyonlu dinamik elemenlerde sağ yönü sol yöne göre yaklaşık iki kat daha fazla tercih etmişlerdir.

Sonuç: Mükemmel zamanlama ve doğru vücut tekniği ile hareketleri hatasız gerçekleştirmek için aşırı tekrarlar yapmak vücutta yüklenmelere, mikro travmalara, kas hasarlarına ve asimetrilere neden olabilir. Kompozisyonun koreografik tasarımları oluşturulurken vücudun her iki tarafındaki yük dengesine dikkat edilerek koruyucu önlemler alınabilir.

Anahtar Kelimeler

Rotasyonlu dinamik elementler, Rotasyon yönü tercihleri, Bireysel rutinler, Performans analizi, Ritmik cimnastik.

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INTRODUCTION

Rhythmic gymnastics (RG) includes movements (body and apparatus) that differ from one another in regards to the use of plane, axis, level, direction, trajectory, and speed, in perfect harmony with the

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music. The specific moves performed with expressiveness, plasticity, and rhythmicity are criteria for technical mastery in RG (Gateva, 2023). The body difficulties (DBs), apparatus difficulties (DAs), dynamic elements with rotation (Rs), dance steps, and body waves are elements of a competition routine. All these components are developed according to the gymnast's performance level and the latest competition rules. The duration of the routine is 1.5 minutes. In this short time, coaches try to create effective, beautiful compositions and increase the difficulty score of the composition. R's are one of the components that affect the DB score. In the senior category, each routine contains a maximum of five R's. The R requires a high throw of the apparatus followed by two (a minimum base rotation of the body) or more body rotational movements [the pre-acrobatic elements (PAs), the vertical rotations (VRs), and the DBs with rotation] followed by the catch. The body rotations can also be performed during the throwing and catching of the apparatus. The R-value (score) may increase with additional criteria (special body and apparatus movements) (FIG, RG-CoP, 2022-2024) and coaches tend to design content-rich R's to improve their gymnast's body difficulty score and therefore the final score.

The movements used in an R are complex coordination movements and require a good orientation ability and perfect timing. In this movement combination, the appropriate level of force and velocity are also required to reach the correct position of the body. Inability to get a good position, a small mistakes while throwing the apparatus, technical faults in rotations cause mistakes when catching the apparatus, and R is not counted if the apparatus is lost. In Rs, the PAs (13 types), the VRs (5 types and also involves DB with rotation 360° or more with a value of 0.10 point), DBs with rotation of 360° or more with a value of 0.20 point or more are types of body rotations used. A rotational movement in one R cannot be used in another R in a routine. The PAs and VRs can be executed with different starting/ending positions and leg movements in different variations (FIG, RG-CoP, 2022-2024). The PAs (fish flops, cartwheels, lateral rotations, rotation with raised leg), the VRs (flight-jump/skip/hop with turn, standing 2 feet-turning steps or rotation with two feet on the floor, standing 1 foot-rotation with one foot on the floor, seated-lateral roll, lying-lateral roll) and DBs can be executed in the right or left rotational directions. However, walkovers, rolls (although not in all rolls, sometimes there may be a small directional preference with one shoulder touching the floor), chest rolls, and dive leaps are executed also without using the rotational direction in PAs. Coaches try to develop gymnasts' rotational body movements at an early age. Because it takes a long time to acquire the habit of correct body position (with proper body/apparatus technique and control) in these multidirectional body rotation movements. Performing a movement or combination of movements without mistakes with music and special movements of the apparatus requires more repetitions in training. If these repetitions are executed more in one direction, one side of the body may be exposed to more physical load (unilateral biomechanical) and these loads can predispose to injuries.

Injury rates and injury types vary according to the athlete's skill level (Feeley et al., 2016). However poor load management has been defined as a significant risk parameter for sports injuries (Soligard et al., 2016). It has been reported that 85% of elite rhythmic gymnasts have muscle-tendon unit injuries (Zetaruk et al., 2006). The risk of overuse injuries may also increase if element repetition is not well-balanced for excellent skills (Denton, 1997; Grueva-Pancheva, 2022; Tayne, Bejarano-Pineda and Hutchinson 2021). The overuse injury rate in rhythmic gymnasts was determined to be 76.7% (Gulati et al., 2022). Studies have been carried out on this subject (Frutuoso et al., 2016; Kutlay et al., 2001; Starosta, 2018). The differences in technical skill between the two sides of the body are disadvantageous because athletes may later become dependent on preferred or dominant extremities. The asymmetrical impact forces, joint torques, and muscle forces may lead to further bilateral changes in the biomechanics of the movement (Parrington and Ball, 2016). It has been stated that movement symmetry can improve technique, reduce physical loads on dominant limbs, and prevent injuries (Jastrejevskaya, 1995; Starosta, 2018).

The motor preference tasks show an individual's tendency for laterality (Utesch et al., 2016). In skills of rotations about one or more body axes, athletes usually prefer one or the other rotation direction (Heinen et al, 2012; Heinen et al., 2016). It has been observed that rhythmic gymnasts prefer the right direction more in the BD rotations (Kutlay and Tatlıbal, 2023). Generally, rotations and rotation directions performed without mistake and with the correct technique are preferred when creating the composition. Excluding preparatory and control training, an elite senior gymnast participates in podium training and C I (Qualification competitions) at a competition. If the gymnast competes on four apparatus, she will execute a maximum of five Rs in each routine. This totals forty Rs. Moreover, this

number will be even higher in the same competition for successful gymnasts participating in All-around Finals (C II) and Finals (C III) competitions. These conditions potentially contribute to excessive usage of one side of the body. A balance can be achieved between excessive movement repetitions and the loads that may be exposed.

The components and choreographic features in elite gymnasts' routines have always been of interest and can provide valuable information. The purpose of the study is to analyze the rotation types, numbers, frequencies, and preferred rotation directions in “dynamic elements with rotation” in all routines of rhythmic gymnasts.

METHOD

Model of the research

A retrospective analysis was conducted in this study. The retrospective research model is a method based on analyzing existing data to examine events, situations, or processes that occurred in the past. In this model, researchers conduct analyses using available records, documents, surveys, or other data sources. Within this framework, the types, numbers, frequencies, and preferred directions of rotations in "dynamic elements with rotation" within rhythmic gymnastics routines have been examined using a retrospective approach.

The universe of the research

84 elite senior gymnasts from 38 countries participated in the 39th European Championships in Rhythmic Gymnastics (RG) held in 2023. After the Qualification Competitions (C I), twenty-four gymnasts may qualified to participate in the All-around Final Competitions (C II). The C II routines (n=96) (hoop, ball, clubs, and ribbon) of the individual rhythmic gymnasts (n=24) (aged 19.8 ± 3.3) were examined. The official competition informations were taken from the 39th European Championship Results Book, which was available on the FIG's official website under the "Gymnastics events" section (“Gymnastics events”).

Data collection tools of the research

The types, numbers, frequencies, and preferred directions of rotations in “dynamic elements with rotation” (R) in gymnasts' routines were analyzed. The pre-acrobatic elements (PAs), the vertical rotations (VRs), and the body difficulties (BDs) (with rotation) in R's were examined. R’s [without significant mistake in execution (like losing apparatus)] with a minimum of two base rotations under the flight of apparatus (complete 360° for each base rotation) were considered. BD (value 0.20 points or more) with rotation 360° or more were taken into consideration. Rs were not scored, only which rotation the gymnasts performed (number and percentages), and their preference directions in these rotations were examined. The same rotation in an R can be performed more than once (e.g. VR no 1, 2), or serially (e.g. jumps, illusions, roll forwards). Therefore, it was also examined according to each rotation performed. RG-Code de Pointage (FIG, RG-CoP, 2022-2024) was considered in the examination of all Rs. Although not always, gymnasts perform a slight directional preference in the Rolls and Fish flops (forward and backward) with one shoulder touching the floor. For this reason, it was evaluated within the scope of rotations performed without using direction. The routines that were documented during the competitions were analyzed to obtain the data. The analyses of C II routines were evaluated simultaneously by two RG judges (International and National level). Itwas recorded with the symbolic writing used in RG. When there was a difference in analysis between the judges, the video recording of the competition routine was re-checked, and the symbolic writing of movements were compared. The rotation types, numbers, frequencies, and preferred rotation directions in “dynamic elements with rotation” were recorded as a common opinion.

Data analysis of the research

Descriptive statistical analyses were made using the IBM SPSS 25.0 statistics program. Values were presented as frequencies, percentages (%), and Mean±Standard Deviation. The quantity (number) and percentage values of each rotation type (with and without direction) carried out in R's were calculated for each routine.

FINDINGS

The rotation types, numbers, frequencies, and preferred rotation directions in "dynamic elements with rotation" in Rs are given below in the tables.

Table 1. The numbers of rotations and types of body rotation in R's

n=96 (Routines)	Hoop (n=24) $\bar{x}$ and SD	Ball (n=24) $\bar{x}$ and SD	Clubs (n=24) $\bar{x}$ and SD	Ribbon (n=24) $\bar{x}$ and SD	All Routines $\bar{x}$ and SD
NRT	8.5 ± 2.6	8.3 ± 1.1	9.0 ± 1.7	7.4 ± 1.5	8.3 ± 0.95
NR	15.3 ± 2.8	14.0 ± 1.8	14.9 ± 2.4	13.3 ± 2.9	14.4 ± 1.6
The mean value of the total number of body rotations performed by all gymnasts on four routines/apparatus					57.5 ± 6.5

N; Total number of routines, n; Number of routines, $\bar{x}$ and SD; Mean and Standard Deviation, NRT; Number of rotation types, NR: Number of rotations (when each rotation is considered)

The clubs routines in R's had the highest rotation type. The highest number of rotations was observed in the hoop routines. In all routines, the number of rotation types was found to be 8.3 ± 0.95, and considering each rotation the number of rotations was determined as 14.4 ± 1.6. The total number of body rotations performed by all gymnasts on four apparatus was determined as 57.5 ± 6.5 (see Table 1).

Table 2. The types, numbers, percentages, and directions of rotations preferred by gymnasts in Rs.

n=96 Body Rotation Types	PD	Hoop (n=24) PR (%)	Hoop (n=24) NR (Number)	Ball (n=24) PR (%)	Ball (n=24) NR (Number)	Clubs (n=24) PR (%)	Clubs (n=24) NR (Number)	Ribbon (n=24) PR (%)	Ribbon (n=24) NR (Number)
BD Jump	R	29.2	7	37.5	9	41.7	10	20.8	5
(With Rotation)	L	8.3	2	8.3	2	8.3	2	8.3	2
BD Illusion	R	12.5	3	12.5	3	8.3	2	12.5	3
	L	75.0	18	70.8	17	62.5	15	70.8	17
PA no									
1	-	83.3	20	95.8	23	70.8	17	75.0	18
2	-	45.8	11	66.7	16	70.8	17	29.2	7
3	R	79.2	19	62.5	15	32.5	9	58.3	14
	L	12.5	3	20.8	5	16.7	4	4.2	1
4	-	83.3	20	70.8	17	83.3	20	75.0	18
5	-	8.3	2	16.7	4	37.5	9	4.2	1
6	-	4.2	1	4.2	1	0.0	0	4.2	1
7	-	0.0	0	0.0	0	8.3	2	0.0	0
8	-	12.5	3	0.0	0	8.3	2	4.2	1
9	-	0.0	0	0.0	0	8.3	2	0.0	0
10	-	0.0	0	0.0	0	0.0	0	0.0	0
11	R	4.2	1	0.0	0	29.2	7	16.7	4
	L	4.2	1	8.3	2	29.2	7	29.2	7
12	-	0.0	0	0.0	0	4.2	1	0.0	0
13	R	0.0	0	0.0	0	0.0	0	8.3	2
	L	20.8	5	20.8	5	20.8	5	20.8	5
VR no									
1	R	83.3	20	91.7	22	87.5	21	75.0	18
	L	12.5	3	8.3	2	12.5	3	12.5	3
2	R	79.2	19	83.3	20	83.3	20	75.0	18
	L	12.5	3	8.3	2	12.5	3	12.5	3
3	R	33.3	8	41.7	10	50.0	12	29.2	7
	L	8.3	2	4.2	1	12.5	3	4.2	1
4	R	62.5	15	66.7	16	62.5	15	54.2	13
	L	25.0	6	25.0	6	29.2	7	25.0	6
5	R	8.3	2	8.3	2	0.0	0	8.3	2
	L	37.5	9	4.2	1	4.2	1	4.2	1
Total	R	64.4	94	69.3	97	65.7	96	65.2	86
	L	35.6	52	30.7	43	34.3	50	34.8	46

n; Total number of routines, n; Number of routines on each apparatus, BD; Body difficulty, PA; The Pre-acrobatic element, VR; The vertical rotation, PD; Preferred direction, R; Right, L; Left, PR; Percentage of rotations performed by gymnasts, NR; Number of rotation (preferred by gymnasts). The Pre-acrobatic elements: 1; Walkovers forwards, 2; Walkovers backward, 3; Cartwheel, 4; Roll forwards, 5; Roll backward 6; Chest rolls forward, 7; Chest rolls backward, 8; Fish flop forwards, 9; Fish flop backward, 10; Lateral rotation passing through a bridge, ending with a kick into split, 11; Lateral rotation with trunk arched back 12; Dive leap, 13; Rotation with raised leg (like an illusion but not DB). The vertical rotations: 1; Flight-jump/skip/hop with turn, 2; Standing two feet turning steps or rotation with two feet on the floor, 3; Standing one foot-rotation with one foot on the floor, 4; Seated lateral roll, with or without passing through split, 5; Lying lateral roll (FIG, RG-CoP, 2022-2024).

The rotations with BD jump were mostly performed on the clubs routines (10 gymnasts, 41.7%), and the right direction was preferred. Rotations with BD Illusion were mostly performed on the hoop routines (18 gymnasts, 75%) and the left direction was preferred more. In the PAs performed without using direction, PA 1 in the ball routines (23 gymnasts, 95.8%), PA 2 in the clubs routines (17 gymnasts, 70.8%), and PA 4 in the hoop and clubs routines (20 gymnasts, 83.3%) were mostly performed. In the PAs performed using direction, PA 3 was performed more frequently (in the hoop routines, 19 gymnasts, 79.2%) and the right direction was the most preferred. In the VRs, VR 1, in ball routines (22 gymnasts, 91.7%), VR 2, in ball and clubs routines (20 gymnasts, 83.3%), and VR 4, in ball routines (16 gymnasts, 66.7%) were mostly performed the right direction was more preferred. In total, in all rotations performed using direction, the right direction was chosen in numbers ranging from 86 to 97 (64.4% and 69.3%, respectively), and the left direction was preferred in numbers ranging from 43 to 52 (30.7% and 35.6%, respectively) (see Table 2). This result shows that the right direction is preferred approximately twice as much as the left direction.

Table 3. Considering each rotation, the types, numbers, percentages, and directions of rotations preferred by gymnasts in Rs.

n=96		Hoop (n=24)		Ball (n=24)		Clubs (n=24)		Ribbon (n=24)	
Body Rotation Types	PD	PR (%)	NR (Number)	PR (%)	NR (Number)	PR (%)	NR (Number)	PR (%)	NR (Number)
BD Jump	R	82.4	13	75.0	9	83.3	10	71.4	5
(With Rotation)	L	17.6	4	25.0	3	16.7	2	28.6	2
BD Illusion	R	14.3	9	15.0	9	11.8	6	15.0	9
	L	85.7	54	85.0	51	88.2	45	85.0	51
PA no									
1	-	-	22	-	29	-	20	-	19
2	-	-	11	-	17	-	18	-	7
3	R	86.4	19	78.3	18	73.3	11	94.4	17
	L	13.6	3	21.7	5	26.7	4	5.6	1
4	-	-	41	-	31	-	35	-	37
5	-	-	2	-	4	-	9	-	1
6	-	-	1	-	1	-	0	-	1
7	-	-	0	-	0	-	2	-	0
8	-	-	3	-	0	-	2	-	1
9	-	-	0	-	0	-	2	-	0
10	-	-	0	-	0	-	0	-	0
11	R	50	1	0.0	0	50.0	7	36.4	4
	L	50	1	100	2	50.0	7	63.6	7
12	-	-	0	-	0	-	1	-	0
13	R	0.0	0	0.0	0	0.0	0	28.6	2
	L	100	5	100	5	100	5	71.4	5
VR no									
1	R	86.4	51	92.0	46	87.5	49	88.0	44
	L	13.6	8	8.0	4	12.5	7	12.0	6
2	R	85.5	47	91.8	45	85.3	52	86.0	43
	L	14.5	8	8.2	4	14.7	9	14.0	7
3	R	80.0	8	90.9	10	80.0	12	87.5	7
	L	20.0	2	9.1	1	20.0	3	12.5	1
4	R	65.1	28	66.7	26	71.1	27	69.2	27
	L	34.9	15	33.3	13	28.9	11	30.8	12
5	R	18.2	2	66.7	2	0.0	0	66.7	2
	L	81.8	9	33.3	1	100.0	1	33.3	1
Total	R	66.7	242	67.2	225	65.4	229	68.1	216
	L	33.3	121	32.8	110	34.6	121	31.9	101

n; Total number of routines, n; Number of routines on each apparatus, BD; Body difficulty, PA; The Pre-acrobatic element, VR; The vertical rotation, PD; Preferred direction, R; Right, L; Left, PR; Percentage of rotations performed by gymnasts (considering each rotation), NR; Number of rotation (preferred by gymnasts, considering each rotation), The Pre-acrobatic elements (PA): 1; Walkovers forwards, 2; Walkovers backward, 3; Cartwheel, 4; Roll forwards, 5; Roll backward 6; Chest rolls forwards, 7; Chest rolls backward, 8; Fish flop forwards, 9; Fish flop backward, 10; Lateral rotation passing through a bridge, ending with a kick into a split, 11; Lateral rotation with trunk arched back 12; Dive leap, 13; Rotation with raised leg (like illusion but not DB). The vertical rotations (VR): 1; Flight-jump/skip/hop with turn, 2; Standing two feet turning steps or rotation with two feet on the floor, 3; Standing one foot-rotation with one foot on the floor, 4; Seated lateral roll, with or without passing through a split, 5; Lying lateral roll (FIG, RG-CoP, 2022-2024).

The rotations with BD jump were mostly executed in hoop routines [a total of 17 rotations were performed, 13 of which were used in the right direction (82.4%) and 4 in the left direction (17.6%)]. The rotations with BD Illusion were mostly performed in hoop routines [a total of 63 rotations were

executed, 9 of which were in the right (14.3%) and 54 in the left direction (85.7%)]. In the PAs performed without using direction, PA 1 in the ball routines (29 rotations), PA 2 in the clubs routines (18 rotations), and PA 4 in the hoop routines (41 rotations) were performed mostly. In the PAs performed with using direction, PA 3 was the most preferred and the highest number of rotations were performed in the hoop and ball routines. In the hoop routines, a total of 22 rotations were used [19 rotations to the right (86.4%) and 3 rotations to the left direction (13.6%)]. In the ball routines, a total of 23 rotations were done [18 rotations to the right (78.3%) and 5 rotations to the left direction (21.7%)]. In these rotations, the right direction was the most preferred. In the VR rotations, VR 1 in the hoop routines [a total of 59 rotations were performed, 51 of which were in the right (86.4%), 8 in the left direction (13.6%)], VR 2 in the clubs routines [a total of 61 rotations were executed, 52 of which were in the right (85.3 %), 9 in the left direction (14.7%)] and VR 4 in the hoop routines [a total of 43 rotations were performed, 28 of which were in the right (65.1%), 15 in the left direction (34.9%)] were mostly performed. Also, in these rotations, the right direction was the most preferred. In total, it was determined that the right direction was preferred between 216 and 242 rotations (65.4% and 68.1%, respectively); the left direction was preferred between 101 and 121 rotations (31.9% and 34.6%, respectively) (see Table 3). These results emphasize that the right rotation direction preference is more dominant than the left direction.

DISCUSSION

RG, a sport practiced with aesthetic and technical movements accompanied by music, requires high-level motor control (Jastrjembskaia and Titov, 1999, Jastrejevskaya, 1995), and the experiences acquired in the early years of life, significantly contribute to the success (Purenović-Ivanović et al., 2016). Numerous repetitions are performed for all perfect movements. Some body segments and movement directions of movement are used more. If both sides of the body are not used balancedly, unilateral loads may cause problems. There are thirteen PAs, five VRs (variety of rotation can be increased with variations), and BD with rotation that can be used in Rs (FIG, RG-CoP, 2022-2024). In this stud, the number of rotation types was found to be 8.3 ± 0.95 and it was observed that gymnasts partially executed a limited variety of rotation types. Also, in gymnasts' tendencies, the lateral differentiation of movements was observed in rotations performed with directional preference used in Rs.

In RG the longitudinal, transverse, lateral axes, and combined rotations are used in rotations (Gateva, 2023). R's are one of the most attractive movements of a composition in terms of the use of space. Each of R takes approximately 2 or 5 seconds, and the gymnast (senior) can perform maximally five times in a routine. In R's, the apparatus is thrown into the air powerfully with an elegant body movement, body rotations are performed under the flight of the thrown apparatus, and then the apparatus is caught with a beautiful body movement. Rotational body movements used during the flight of the apparatus also give a dynamic feature to the routine. All these movements are enriched by body- and apparatus-specific criteria. It is necessary to require physical skill and have an improved proprioception. The motor coordination between the body and apparatus movements means that every movement must start and end only at an optimal time during the performance. The execution of a movement either early or late might alter other kinematic properties and result in mistakes. Creative movements always attract attention, and the movements executed by successful gymnasts are followed with interest by the other gymnasts. In our study, it was observed that gymnasts mainly tend to use similar rotations. If we had examined C I, we would probably encounter similar features.

In all sports we can see lateralized behaviors and this is obvious in athletes' use of their hands, feet, eyes, or turning direction when performing specific tasks (Loffing et al., 2016). The most complex movements are those that involve the whole body connected with turns. Use of unilateral body segments or excessive use of the same direction may create different mechanical loads on the body. The symmetrical structure of the human body allows the performance of both asymmetrical and symmetrical movements. The symmetrization of the movements refines technique, decreases physical loads on the dominant limbs and back (spine), and prevents sports injuries (Jastrejevskaya, 1995; Starosta, 2018). In addition to all these, equalizing the capability of both body sides may be advantageous for rhythmic gymnasts because it enriches the handling of apparatus and makes the choreography more artistically appealing.

Gymnasts' preferred movements and methods may evolve, and the rules/regulations of the competition may have an impact on these developments as well. In an analysis investigation, it was observed that the number of body rotations performed in Rs increased as the weight of the apparatus decreased (Batista, 2017). The ribbon apparatus has the lowest weight. Whereas in our study, the highest number of body rotations were executed on the hoop routines and the least number of body rotations were observed on the ribbon routines. Also, according to the rotation types, most rotation types were executed in the clubs routines and the least in the ribbon routines (see Table 1). Since the fabric of the ribbon has a feature that can easily change shape according to the movements, it is much more difficult to control than other apparatus. For this reason, gymnasts may have performed fewer rotations on the ribbon apparatus.

In the study, considering each rotation, the number of rotations was determined as 14.4 ± 1.6. In the training analyses of the competition period, the gymnasts were stated to perform routine repetitions 16-30 times in each training with 2 or 4 apparatuses per day (Jastrjembskaia and Titov, 1999). Also, in a routine, gymnasts execute body rotations in movements such as BDs, DAs, and dance steps in addition to Rs. Therefore, these numbers determined in our study may increase even further. Additionally, gymnasts participate in competition preparations, control training, competition training, official training (podium), and Qualification competitions (C I). If the gymnasts are successful, they also participate (within the scope of the same competition) in the competition types such as C II and C III. Competition routines and all these special movements are repeated many times. In this study, the total number of body rotations executed by all gymnasts on four apparatus was determined as 57.5 ± 6.5 in C II (see Table 1). In all stages, from competition preparation to the end of the competition, these numbers may increase several times. If supportive exercises and appropriate recovery strategies are not implemented in training or if choreographic planning of movements with balanced load distribution on both sides of the body is not considered, the loads resulting from movement repetitions can cause early fatigue and acute or chronic injuries. These results could therefore be potentially important.

In the study, the BD jump was mostly performed on the clubs routines, and the right direction was preferred. The BD Illusion was mostly executed in the hoop routines and the left direction was most preferred. In the PAs performed without using direction, PA 1 in the ball routines, PA 2 in the clubs routines, and PA 4 in the hoop and clubs routines were performed mostly. In the PAs performed with using direction, PA 3 was performed more, and the right direction was preferred more. In the VRs, VR no 1, 2, and 4 were more performed and the right direction was preferred more. When the total of all rotations executed using the direction was examined, it was found that the right direction was preferred more in the routines between 86 and 97 (64.4% and 69.3%, respectively) (see Table 2). These results show more largely that the right direction preference was more dominant (approximately twice as much) than the left direction. The BD Illusion was the most preferred in all rotational movements. VR 1 and 2 were the most performed rotation types in all PAs and VRs. VRs were executed in greater numbers than PAs. Interestingly PA no 7, 9, 10, and 12 were established to be less preferred or not used compared to other rotations (see Table 2). The coordination of each body segment and this segment of compatibility with the apparatus is important for a high-skilled rotation. Gymnasts select rotational patterns according to the apparatus's features and their level of ability.

Gymnasts exhibit particular direction preferences when executing simple and complex skills and one important directional tendency is that of rotational preference (Bessi et al., 2016). Gymnasts generally choose the direction of rotation that they are accustomed to, can do comfortably, and can perform technically without mistakes. Another issue was carried out in Rs, the same rotation can be used multiple times in succession or series (contributes 0.20 points to the value of R when rotations are performed serially) (FIG, RG-CoP, 2022-2024). With this point of view in our study, considering each rotation, the rotations with BD jump and BD Illusion were mostly used in hoop routines. The right direction was preferred in BD jump (82.4%), and the left direction was preferred in BD Illusion (85.7%). The BD Illusion was most performed in all rotational movements (see Table 3). This movement is visually elegant, but it is difficult to perform in R's (during the catch, rotation timing must be perfect). The number of rotations and additional criteria increases the score value of a R. Criteria selection may vary depending on the gymnast's skill level and the features of the apparatus used.

In this study, the PAs performed without using direction, PA 1 in the ball routines, PA 2 in the clubs routines, and PA 4 in the hoop routines were mostly executed. PA 4 also contributes 0.20 points to the R value when applied serially, such as BD jump and BD Illusion. This may be the reason why it is preferred mostly. In the PAs performed with using direction, PA 3 in the hoop and the ball routines was the most preferred (see Table 3). The characteristics of the apparatus (weight, size, and shape) used in RG are different from one another, and these differences may also affect the movement patterns and body rotation preferences. Since the clubs apparatus is double and the fabric of the ribbon is long (6 m), it may be tough to control during body rotational movements. For this reason, this rotation may have been performed more in hoop and ball apparatus in comparison to other apparatus. Additionally, in this study, in the VRs, VR 1 in the hoop routines, VR 2 in the clubs routines, and VR 4 in the hoop routines were mostly performed and the right direction was the most preferred (see Table 3). Lower rotation numbers were observed in the ribbon apparatus when all rotation types were considered. The apparatus feature may have influenced the rotation selection. Finally, in our study, considering each rotation in total, it was observed that the right direction was preferred more in all routines between 216 and 242 rotations (65.4% and 68.1%, respectively); the left direction was preferred between 101 and 121 rotations (31.9% and 34.6%, respectively) (see Table 3). The right direction preference is more dominant (approximately twice as much) than the left.

The rotations in Rs are performed using very different speeds, levels, planes, axes, and in these movements require many repetitions to acquire the proper sense of joint position, speed, and force perception. Repetitive load is believed to be a risk factor for many overuse injuries (Feeley et al., 2016). Muscular fatigue, decreased muscle control, and poor technique are known to lead to injuries. Injuries can be persistent and pose a substantial problem for athletic careers and quality of life. Therefore, risk analysis of sports injuries can provide important information about the athletes' health and ability to continue sports for a long time (Bahr and Holme, 2003). We wanted to raise awareness of these issues. Proper organization of movements during routine preparation can protect the gymnast from problems that can occur due to unilateral movement loading. Therefore, exercises that support the contralateral side of the body should be included in training. For gymnasts, developing customized training programs for both everyday practice and competition is essential. Some gymnasts are more prone to injury than others (with an insufficient training background). Especially the assistant coaches to record the type and number of all movements (body and apparatus) may contribute to the organization of training. However, precautions can still be taken through special training programs or training equipment (supporting non-dominant body parts).

Our study revealed the most used rotations and rotation direction preferences in R's. There are limited studies on dynamic elements with rotation in the literature. With developments in digital science and technology, performance analysis and optimization will become much more advanced in the future. Advanced performance analysis systems exhibit the potential to promote innovative technologies for improving training and competitive performance, prolonging athletic careers, along with reducing sports injuries (Zhu et al., 2023).

This study has some limitations. In PA no 4, 5, 8, and 9 gymnasts' rotation direction preference was also observed (passing through the right or left shoulder). However, in the direction preference analysis of this study, rotations with obvious direction preferences were considered. In the future, direction preferences in these rotations can be included in studies. In future studies, the total R time for each routine can be calculated regarding movement speed and correlated with BD score and competition success.

CONCLUSION

In Rs, the gymnasts executed a limited variety of types of rotations and in gymnast's tendencies, the lateral differentiation of movements was observed. Training may also have possible effects on lateral tendencies in movement. The highest number of body rotations were used on the hoop routines. When examined according to the number of rotation types, the highest number of rotation types were performed in clubs routines. In Rs, the right direction preference was more dominant (approximately twice as much) than the left. BD Illusion was the most preferred movement in all rotational movements.

VR 1 and 2 were the most preferred rotation types in all PAs and VRs. The number of VRs executed was higher than the PAs.

SUGGESTIONS

Our findings highlight the importance of protective exercises. In choreographic preparations, the body's load balance can be maintained by using the other direction or non-dominant body part in movement selections other than Rs. Contralateral training and supportive exercises may be recommended during preparatory training. Our results may provide insight that can assist in the monitoring, planning, and altering of gymnasts' training programs.

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