IS THERE A DIFFERENCE BETWEEN RHYTHMIC AND ARTISTIC GYMNASTS IN ACTIVE AND PASSIVE FLEXIBILITY OF THE LOWER LIMBS?

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Abstract:

Flexibility is the first connection between rhythmic and artistic gymnasts, but it is also motor ability that distinguishes them at the sporting level. The main goal of this research was to determine whether there was a significant difference in active and passive flexibility of the lower limbs among rhythmic and artistic gymnastics competitors. The sample of participants consisted of 18 gymnasts, out of which nine were rhythmic gymnasts and the other nine artistic gymnasts, from the junior and senior age category (13 to 18 years). In the research, the following tests were used to assess active and passive flexibility, constructed by the International Gymnastics Federation (FIG): front split with hand support (FSWH), front split without hand (FSWOH), side split with hand support (SSWH), side split without hand (SSWOH), back split "penche" (BSP), back split with hand support (BSWH), and forward-backward split between two blocks (FBS). In order to analyse the difference between the two groups of participants (rhythmic and artistic gymnasts) in flexibility tests, Mann-Whitney U test was used, the test for independent samples. To determine the difference between the dominant and non-dominant leg, Sign test was used to see whether there was a statistically significant difference between the arithmetic means of the tests performed by the rhythmic and artistic gymnasts, with an error of $p<.05$. Results showed statistically significant difference between the rhythmic and artistic gymnasts in tests of active and passive flexibility. Differences are in the dominant leg, which was expected because each element is performed on the dominant leg.

Key words: *flexibility, dynamic, inactive, preferred leg, non-preferred leg*

Introduction

Both sports, rhythmic and artistic gymnastics belong to the conventional aesthetic disciplines where the movement is prescribed by the Code of Points (FIG, 2022b, 2022a). Women artistic gymnastics consists of four disciplines: vault, uneven bars, balance beam, and floor. In rhythmic gymnastics all routines are performed on the floor using five apparatuses: rope, hoop, ball, clubs, and ribbon. The disciplines of women's artistic gymnastics mostly similar in some leaps, jumps, hoops, and turns to the rhythmic gymnastics are floor and balance beam. One of the most fundamental physical components of rhythmic gymnastics is flexibility. What mostly differs artistic and rhythmic gymnastics from non-aesthetic sports is flexibility or ROM (range of motion) (Sands, et al., 2016a). Ability to reach ROM during the performance of technical aspects greatly influences the level of technical and artistic excellence that rhythmic gymnasts are able to accomplish. A strong correlation between flexibility degree and skill of rhythmic gymnasts has been found in several studies (Boligon, Deprá & Rinaldi, 2015; Vernetta, Peláez-Barrios, & López-Bedoya, 2020). There are three types of flexibility: dynamic, active, and passive (also known as static) flexibility (Alter, 1998; Prentice, 1994). The maximum range of motion a joint can attain with the help of an external force, like gravity or manual assistance, without taking into account movement speed or muscular exertion, is known as passive flexibility (Prentice, 1994). The greatest range of motion an athlete may achieve with momentum and his or her own muscle work is known as dynamic flexibility (Prentice, 1994). The maximum range of motion that an athlete may achieve utilizing only their own muscles is known as active flexibility (Alter, 1998).

There are five widely used stretching techniques: proprioceptive neuromuscular facilitation (PNF), dynamic stretching, ballistic stretching, static-active stretching, and static stretching. The majority of the literature indicates that PNF is the most successful method, however, vibration training has also started to gain popularity as an effective technique for increasing flexibility in recent years (Uzunov, 2008). Middle childhood, the period from six to eleven years, is emphasized as a key time for the development of flexibility and is considered a "window of opportunity" (Lloyd & Oliver, 2012). One of the possible mechanisms behind this assumption is increased flexibility and reduced muscle-tendon stiffness, associated with childhood, which enables a greater range of motion to be achieved and thus can make flexibility training more effective (Kubo, Kanehisa, Kawakami, & Fukanaga, 2001). A meta-analysis by Donti, Konrad, Panidi, Dinas, and Bogdanis (2022), dealing with the issue of whether there is a difference in the effectiveness of flexibility training in children (6-11 years) and adolescents (12-18 years), showed that stretching, without differences, successfully improved range of motion in both children and adolescents, which indicates a contradiction. It is also necessary to emphasize that the importance of flexibility is specific to each sport, so in sports such as gymnastics and dance, children must be able to perform technical elements with a very large range of motion from a young age (7-9 years) (Sands, et al., 2016). Apart from the influence of training, the next question that arises is the influence of puberty on flexibility. During puberty, bones grow faster than muscles, which can result in reduced muscle-tendon extensibility of postural and biarticular muscles, thus limiting ROM (Philippaerts, et al., 2006; Robles-Palazón, et al., 2022; Tanner, 1987). In the research by Mandroukas, Metaxas, Michailidis, and Metaxas (2023), the aim was to investigate and compare the passive ROM in the joints and the strength of rhythmic gymnasts, artistic gymnasts, and controls in the pre-adolescent period. The study concluded that rhythmic gymnasts demonstrated significantly greater flexibility compared to artistic gymnasts, likely influenced by their sport-specific training and demands. Moreover, significant variations in hip flexion between the left and right legs were observed among rhythmic gymnasts (Mandroukas, et al., 2023). These findings underscore the beneficial effects of both rhythmic and artistic gymnastics training on neuromuscular function and relative muscle strength in pre-adolescent individuals (Mandroukas, et al., 2023). The work by Haywood (1980), who investigated the strength and flexibility of rhythmic gymnasts before and after the onset of menstruation, also indicates that there are no significant differences in strength and flexibility before and after the onset of menstruation. The ideal time to develop passive flexibility is between five and eight years of age (Uzunov, 2008). The ideal method for developing passive flexibility according to recommendations (Davis, Ashby, McCale, McQuain, & Wine, 2005; Uzunov, 2008), is holding a stretch for five to 60 seconds with the first 20 to 30 seconds having the highest benefit to duration ratio (Brandy & Iron, 1994; Brandy, Iron, & Biggler, 1997, 1998; McNair, Dombroski, Hewson, & Stanley, 2000; Uzunov, 2008). Recommendations for stretching frequency vary from one to three times per day to five times per week (Davis, et al., 2005). When it comes to preventing injuries, passive flexibility may be especially important for younger gymnasts performing quick, dynamic movements(Funk, Swank, Mikla, Fagan, & Farr, 2003). Studies reveal that, compared to static flexibility, dynamic flexibility, which also includes active flexibility, is far more important for sports performance (McNair, et al., 2000; Prentice, 1994; Roberts & Wilson, 1999; Uzunov, 2008). There are investigations into flexibility and its influence on performance, especially in aesthetic sports. Boligon et al. (2015) have determined how flexibility affects the execution and validation of movements that are typical for rhythmic gymnastics. Silva et al. (2019) investigated genetic predisposition in the definition of the elite rhythmic gymnasts' flexibility phenotype. The tests used to measure flexibility in gymnastics disciplines are reviewed by Vernetta et al. (2020) using data from January 2005 to March 2020 from the PubMed, WOS, Scopus, Sport Discus, and Google Scholar databases. Hölbling, Grafinger, Baca, and Dabnichki (2020) have created a model prototype of a device that increases hip joint ROM, uses flexibility-enhancement reflexes, and offers suitable means for strength training. The purpose of the study by Berisha and Oktay (2021) was to perform a biomechanical analysis of the use of active flexibility in artistic gymnastics movements requiring flexibility, strength, power and other motor skills in addition to mobility (actively moving through a range of motion). Dallas and Kirialanis (2013) investigated how different whole body vibration (WBV) settings affected the flexibility and jumping ability of artistic gymnasts. The goal of the research by Irurtia, Busquets, Carrasco, Ferrer, and Marina (2010) was to describe how flexibility changed in a group of fifteen teenage male gymnasts throughout the period of the entire gymnastics season. D'Anna and Gomez Paloma's (2015) overview of the literature should facilitate the organisation of training plans aiming at improving gymnasts' performance. Acute changes in hip extension flexibility in rhythmic gymnasts were investigated and compared by Karloh et al. (2010) using two different stretching methods. Papia, Bogdanis, Taubekis, Donti, and Donti (2018) researched how an acute session of extended static stretching affected the hip and knee joint range of motion (ROM) and the height of the countermovement jump (CMJ) in nineteen female Gymnastics for All gymnasts. Batista, Garganta, and Avila-Carvalho (2019b) examined potential functional asymmetries in flexibility in gymnasts from Brazilian and Portuguese national teams of rhythmic gymnasts and compared their strength and flexibility levels. In another study the interaction between technical execution score and physical fitness in rhythmic gymnasts of different performance levels was investigated (Donti, Bogdanis, Kritikou, Donti, & Theodorakou, 2016). The purpose of the study by Batista Santos, Bobo Arce, Lebre, and Ávila-Carvalho (2017) was to determine levels of lower limb flexibility and any potential asymmetry indicators between the dominant and non-dominant leg in the gymnasts in Portugal Junior 1st Division. Batista, Garganta, and Avila-Carvalho (2019a) examined both passive and active flexibility and compared them among Portuguese rhythmic gymnasts competing at different levels. Meanwhile, Santos, Lemos, Lebre, and Carvalho (2015) assessed five high-level junior gymnasts (aged 13.60 ± 0.25 years) throughout a sports season for their levels of preferred and non-preferred lower limb active and passive flexibility.

Rhythmic elements of artistic gymnastics are performed on balance beam and floor and some of them are very common elements in rhythmic gymnastics. The main purpose of comparing active and passive flexibility in rhythmic and artistic gymnasts was to observe the difference in flexibility between the dominant and non-dominant leg. Namely, gymnasts (artistic and rhythmic) usually perform elements on the dominant leg and the non-dominant leg is neglected. The aim is to highlight the importance of both active and passive flexibility and to assist coaches in training planning. Our research fills a critical gap by specifically focusing on both active and passive flexibility, providing new insights lacking in the current literature. Insufficient flexibility in artistic gymnastics impedes performance and results in the form of deductions from the final exercise score, particularly in routines requiring five acrobatic and three dance elements on both the floor and balance beam. Non-compliance with dance element rules leads to their non-recognition, directly impacting the final exercise score. For example, failing to execute a leap jump with leg separations at 180° results in deductions ranging from 0.10 to 0.30 points. Leg separations under 135° may result in the element being categorized differently according to the Code of Points, or receiving no difficulty value (FIG, 2022b). Connections of elements, especially on balance beam, connection of turns, must be performed with a step in to turn on the opposite leg (FIG, 2022b). In exercises on beam and floor, the artistry of execution is lost and dance elements are performed at a rather poor level, and more attention is paid to the weight values of acrobatic elements. In this way, the dance elements serve as a „break“ from the acrobatics in the exercise and they are not performed at the level at which they should be performed. Therefore, exercises lose their artistry and become robotic. Same as with artistic gymnasts, rhythmic gymnasts also perform most of the elements only on the dominant leg. In rhythmic gymnastics importance of passive and active flexibility and large ROM is even more emphasised than in artistic gymnastics. Deductions for insufficient flexibility in elements such as balances, rotations, leaps, acrobatic elements, etc., go from 0.1 points for small deviations of body segments, 0.3 points for medium deviations of body segments, to 0.5 points for large deviations of body segments (FIG, 2022a). If the rhythmic gymnast has a large deviation of the body segments during the performance of the element, in addition to the execution penalty of 0.5 points, the commission of BD judges does not count the value of the performed element, whereby the gymnast loses points again (FIG, 2022a). In addition to the execution commission, the artistry commission can also deduct points for insufficient ROM during performance of elements. If the movements of the body segments are not performed with maximum amplitude, width and extension, the artistry commission gives a penalty of 0.3 to 0.5 points (FIG, 2022a).

The importance of flexibility and great ROM in rhythmic gymnastics can be seen in many body difficulties (jumps/leaps, balance, and rotations), as well as in pre-acrobatic elements. For example, in jumps like stag or split leap (with or without ring/back bend of the trunk) and its variations (switch leap, or turning leap “jete en tournant”), balances like front, side or back split (with or without help, with the trunk backward/forward at horizontal/below horizontal, etc.), rotations in front/side/back split with or without help, also with the trunk backward/forward at or below horizontal (“penche”, “Kabaeva”, etc,) and pre-acrobatic elements such as walkovers forwards and backwards, cartwheels, chest rolls etc. For every difficulty of the body and pre-acrobatic element that is not executed with satisfactory amplitude, execution judges deduct 0.1-0.5 pointsfor execution from, depending on how big the deviation of the body segments is.

Goals and hypotheses

The main goal of this research paper is to determine whether there is a significant difference in active and passive flexibility of the lower limbs among rhythmic and artistic gymnastics competitors. Through the conducted tests, coaches gain an insight into the difference between the dominant and non-dominant limb and in this way, they can plan the further training process, so that the differences in limb flexibility, if any, can be reduced and the performance on both limbs can be improved. Therefore, the following hypotheses were set:

H_0: There is no difference in active and passive flexibility between rhythmic and artistic gymnastics competitors.

H_1**:** There is a statistically significant difference in active and passive flexibility between rhythmic and artistic gymnastics competitors.

Methods

Participants

The sample of participants consisted of 18 gymnasts of which nine were rhythmic gymnasts and nine artistic gymnasts from junior and senior age category (13 to 18 years). According to the Participant Classification Framework, gymnasts belonged to the elite/international level (McKay, et al., 2022). Mean values of body height (cm) (Table 1) for rhythmic gymnasts was 160 cm, body mass 47.89 kg, and BMI 18.28. Artistic gymnasts had mean height values of 158 cm, body mass: 50.89 kg, and BMI= 20.32. BMI was calculated by the following formula: $BMI = \frac{weight\ (kg)}{height\ (m^2)}$

Both groups of gymnasts trained in SC Lučko and were of the highest competition level (A programme). They had their training sessions six days a week, from Monday to Saturday, for 6-8 hours a day. The precondition for participation in the research was the absence of any injuries and any other conditions that could negatively affect the performance of the tests or be risky for further deterioration of the gymnast's health. Before the actual start of the research, the trainees and coaches were informed about the goals and potential risks and an informed consent for voluntary participation in the research was signed (approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb). For trainees who were minors, informed consents were signed by their parents.

Description of protocols, measuring instruments and variables

The research was conducted in the sports hall SC Lučko, where the gymnasts have their training routine. Before the tests, the gymnasts warmed up for at least an hour, so that the tests could be performed with the maximum possible amplitude. All respondents did a gymnastic specific warm-up session for at least an hour. The warm-up session consisted of passive and active stretching exercises combined with strength (1-min step out on both extremities, 5-min front, side and back splits on both extremities, 20 x back bends) plus 20 minutes of ballet exercises (20 x *releve*, 10 x b*attement tendu*, 10 x *battement jete*, 10 x *grand battement* jete). After warming up, gymnasts approached the measurer individually and, after explanation and demonstration, performed all seven tests on both extremities. After the first gymnast completed the tests, the next was called and so on until the last gymnast. Each test was recorded and photographed with the camera of a Samsung Galaxy S21+ mobile phone, 30 fps (frame per second) three times whereby the final position on each performed test had to be held for at least two seconds. The camera was 3-m away from the participants, so that the entire performance of the test could be recorded without interruption. No special programme was used for image analysis. The pictures were put into Microsoft Word and lines were drawn according to the degrees that determined the criteria. When the measurer was taking pictures and recording the performance of the test, no tripod was used, the cell phone was held by the hand.

Table 1. Descriptive parameters of basic anthropometric charatcteristic – artistic and rhythmic gymnats

Variable	Valid N AG	Valid N RG	Min AG	Mean RG	Mean AG	Min RG	Max AG	Max RG	Std Dev AG	Std Dev RG
Height (m)	9	9	1,58	1,60	1,53	1,38	1,64	1,79	0,04	0,14
Weight (kg)	9	9	50,89	47,89	47,00	32,00	56,00	60,00	2,98	10,84
BMI (kg/m^2)	9	9	20,32	18,28	19,70	16,00	20,90	20,00	0,44	1,63

Note. AG - artistic gymnasts; RG - rhythmic gymnasts

The measurer used a cell phone to record and take pictures of the entire procedure in order to analyse and assign a mark based on a specific criterion afterwards by three Croatian gymnastics experts (three Brevet judges), who judge major gymnastics competitions (World Cups, European and World Championships) and participate in annual educations conducted by the FIG (World Gymnastics Federation). For each test, criteria were determined by degrees (from 0° to 90°+) for which a corresponding grade (1-10) was given. Grade 1 means that the test performance was the poorest, while grade 10 means that the test performance was the best (Figure 1). In the research, the following tests, constructed by the International Gymnastics Federation (FIG) (Dias, Aleksandrova, Lebre, Bobo, & Fink, 2021) were used to assess active and passive flexibility: front split with hand support (FSWH), front split without hand support (FSWOH), side split with hand support (SSWH), side split without hand support (SSWOH), back split „penche" (BSP), back split with hand support (BSWH), and forward-backward split between two blocks (FBS). The tests: front split with hand support, side split with hand support, back split with hand support, and forward-backward split between two blocks were used to assess passive flexibility, while the front split without hand support, side split without hand support, and back split "penche" were used to assess active flexibility. All tests were performed on both lower limbs (dominant/non-dominant), with the test always starting with the non-dominant leg first. None of the tested gymnasts fell during the performances of the tests in this research. In the case of a fall during the performance, gymnasts can repeat it for a second time, but if the gymnasts are unable to perform the test, the score for their performance was rated as 0. In our research, a similar angular evaluation was employed to align with the criteria published by the International Gymnastics Federation (FIG). This ensured that our methodology was consistent with the established standards, thus enhancing the reliability and comparability of the results.

Table 2 shows the description of the variables and criteria used. For each test (Table 3), criteria were determined, according to which the gymnast was awarded a mark from one to 10. Mark 1 indicated the poorest performance, while mark 10 indicated the best performance.

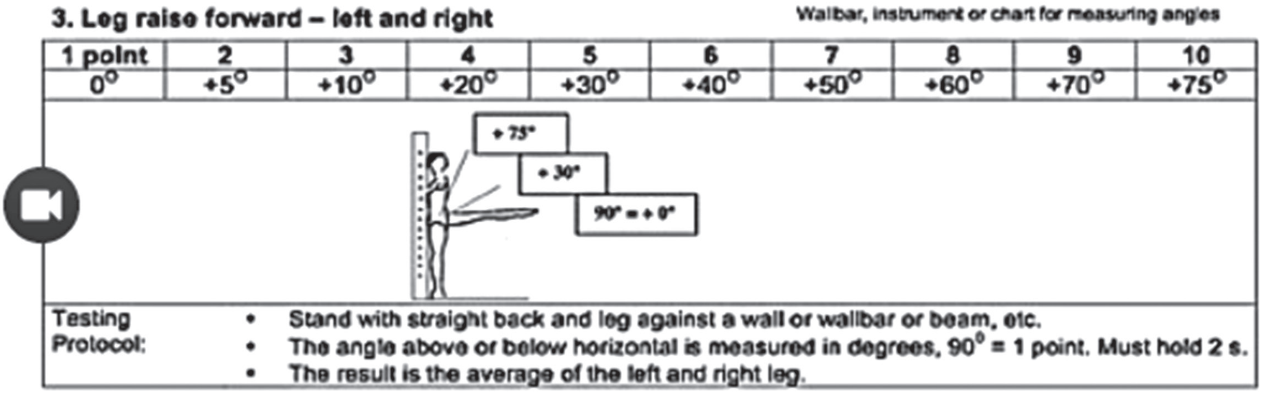

Figure 1. Testing procedure for leg raise forward – left and right.

Table 2. Description of variables

Variable	Description of the variable	Mark
FSWH DOM	Front split with hand support – dominant leg	1 – 10
FSWH NDOM	Front split with hand support – non-dominant leg	1 – 10
FSWOH DOM	Front split without hand support – dominant leg	1 – 10
FSWOH NDOM	Front split without hand support – non-dominant leg	1 – 10
SSWH DOM	Side split with hand support – dominant leg	1 – 10
SSWH NDOM	Side split with hand support – non-dominant leg	1 – 10
SSWOH DOM	Side split without hand support – dominant leg	1 – 10
SSWOH NDOM	Side split without hand support – non-dominant leg	1 – 10
BSP DOM	Back split "penche" – dominant leg	1 – 10
BSP NDOM	Back split "penche" – non-dominant leg	1 – 10
BSWH DOM	Back split with hand support – dominant leg	1 – 10
BSWH NDOM	Back split with hand support – non-dominant leg	1 – 10
FBS DOM	Forward-backward split between two blocks – dominant leg	1 – 10
FBS NDOM	Forward-backward split between two blocks – non-dominant leg	1 – 10
TBF	Trunk bend forwards	1 – 10
SMT	Shoulder mobility test	1 – 10

Table 3. Criteria and marks for each range of degrees

1	2	3	4	5	6	7	8	9	10
0-10°	10 - 20°	20 - 30°	30 - 40°	40 - 50°	50 - 60°	60 - 70°	70 - 80°	80 - 90°	90°+

Front split with hand support (FSWH)

The gymnast stands on her full feet, with the body upright and side facing the Swedish ladder, while holding on to the crossbar at waist level with the nearer hand (Figure 2). At the signal of the measurer, the gymnast raises the non-dominant leg fully extended in front of the body and grabs it with the same hand, pulling it towards the chest as close as possible. When the maximum amplitude has been reached, the gymnast has to keep the front leg position for a minimum of two seconds. During this time, the measurer records and takes pictures of the performance with a cell phone and the recording is later used for analysis and scoring according to certain criteria. It is important to emphasize that all segments of the body of the gymnast must be in a harmonious position: both the shoulders and hips are facing forward, the knees and feet of both legs are fully extended, and the back is straight. When the gymnast has performed the test on the non-dominant leg, the same test is repeated on the dominant leg, only now facing the ladder with her other side.

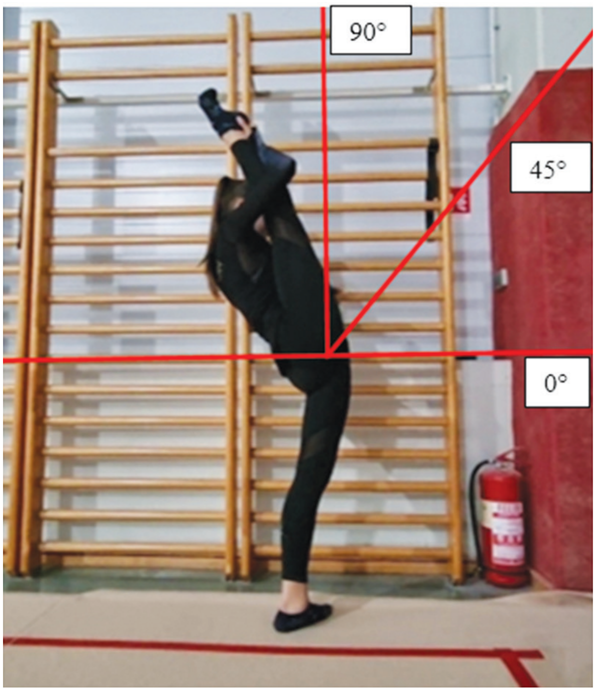

Figure 2. Front split with hand support—Test 1.

Front split without hand support (FSWOH)

The gymnast stands on the full feet, with the body upright, and side facing the Swedish ladder, while holding on to the crossbar at waist level with the nearer hand (Figure 3). At the measurer's signal, the gymnast raises the non-dominant leg in front of the body as high as possible and holds the achieved position for at least two seconds without the help of the hand. The same-sided arm is raised and extended above the head. The entire process is recorded and photographed with a mobile phone by the measurer, so that later analysis can be done, and a mark can be assigned according to a certain criterion. All segments of the body of the gymnast must be in a harmonious position: the shoulders and hips are facing forward, the knees and foot of the raised leg maximally extended, and the back is straight. After performing the test on the non-dominant leg, the gymnast repeats the task on the dominant leg and turns the other side to the ladder.

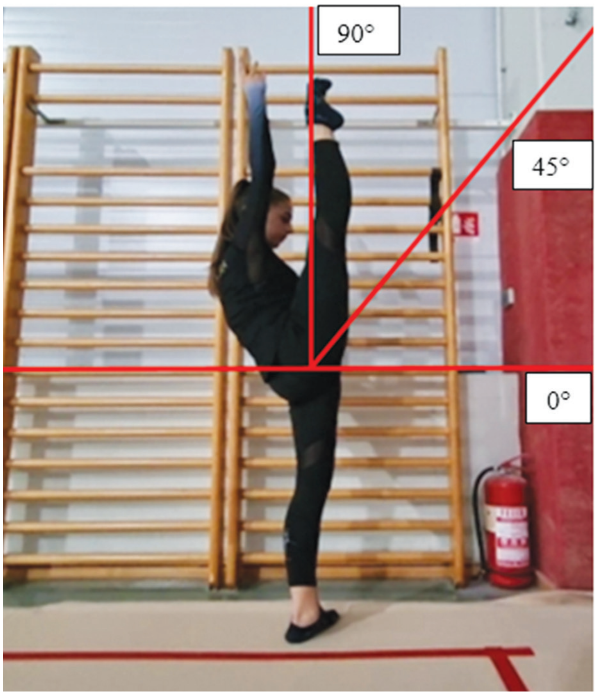

Figure 3. Front split without hand support—Test 2.

Side split with hand support (SSWH)

The gymnast stands on full feet, with the back turned to the Swedish ladder, holding on to the crossbar with one hand at waist level (Figure 4). At the signal of the measurer, the gymnast raises laterally the non-dominant leg and grabs it with the same hand, pulling it towards the shoulder as much as possible. The achieved split position must be maintained for a minimum of two seconds, during which the measurer records and takes pictures of the entire process of performing the task. During the performance, the body of the gymnast should be in a harmonious position, with the knees and foot of the raised leg maximally extended, while the body is upright and looking straight ahead. The same task is executed with the dominant leg.

Side split without hand support (SSWOH)

The gymnast stands on full feet, with the back turned to the Swedish ladder, holding on to the crossbar with one hand at waist height and the other laterally raised shoulder height (Figure 5). At the signal of the measurer, the gymnast raises the non-

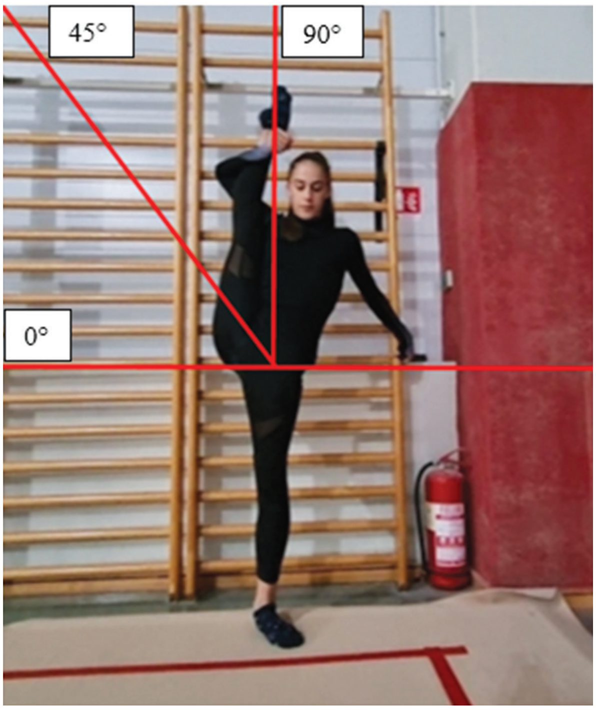

Figure 4. Side split with hand support—Test 3.

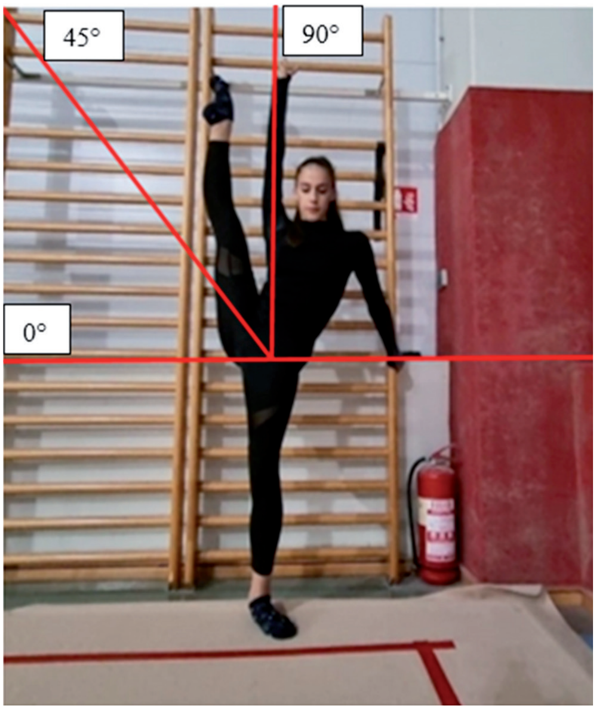

Figure 5. Side split without hand support—Test 4.

dominant leg on the side of the body as high as possible and maintains the achieved position for a minimum of two seconds, without the help of the hand. The task is recorded and photographed by the measurer with a mobile phone, from start to finish. The body of the gymnast during the test performance must be upright, without leaning to the side and with the knees and foot of the raised leg maximally extended. The task is then executed with the dominant leg.

Back split “penche” (BSP)

The gymnast stands with her trunk bent forward below horizontal, with both the legs and arms extended (Figure 6). At the measurer’s signal, the gymnast does a back split into a “penche” position with the non-dominant leg as high as possible and holds the position for a minimum of two seconds. It is important to emphasize that the weight of the gymnast’s body should not be on the hands but on the standing leg. The body of the gymnast also must be in a harmonious position, with both shoulders in the same plane, with both knees and the foot of the upper leg stretched to the maximum. The same task is executed with the dominant leg, while the measurer is recording and taking pictures of the entire process with a mobile phone.

Back split with hand support (BSWH)

The gymnast stands with her chest facing the Swedish ladder, holding on to the crossbar at waist height with both hands (Figure 7). At the signal of the measurer, the gymnast performs a back split with the non-dominant leg as high as possible and

Figure 6. Back split “penche”—Test 5.

grabs the leg with the opposite hand, trying to perform the position of the full, extended split. It is allowed to slightly bend the trunk forwards during the performance of the task, provided that both shoulders are in the same plane and look forwards. Both legs and the foot of the upper leg must be maximally extended. The task is then executed with the dominant leg, while the measurer records the performance and takes pictures with a mobile phone.

Forward-backward split between two blocks (FBS)

To perform this test, two gymnastic blocks, chairs or any kind of elevation are needed. The blocks for both legs must be of the same height (Figure 8). The gymnast performs a forward-backward split between two blocks, while trying to achieve the maximum amplitude of the split and touch the ground with the thigh of the front leg. The hands can be placed on the front block or extended up, provided that the body is upright or slightly bent forward. The body that rests completely on the front leg or deviates from the harmonious position in any way is considered an incorrect performance of the task and is not valid. Both legs and both feet must also be maximally extended. The gymnast must maintain the achieved position of the split for a minimum of two seconds, while the measurer takes pictures of the final position with the mobile phone. The test is repeated on the other leg/side.

Figure 7. Back split with hand support—Test 6.

Data processing

For simple data analysis and processing, Microsoft Excel 365 was used for input and better transparency, while Statistica 14.0.0.15 was used for statistical analysis. Mean, minimum, maximum, standard deviation and normality of distribution were used as descriptive indicators for both groups of participants. The effect size parameter was used to show the practical significance of the results. Effect size was tested by Cohen's d index (Cohen, 1988) with Hedges correction for small samples. In order to analyse the difference between the two groups of participants (rhythmic and artistic gymnasts) in tests of flexibility Mann-Whitney U test was used, the test for independent samples. To determine the difference between the dominant and non-dominant leg Sign test was used that shows whether there is a statistically significant difference between the arithmetic means of the tests performed by rhythmic and artistic gymnasts, with an error of p<.05.

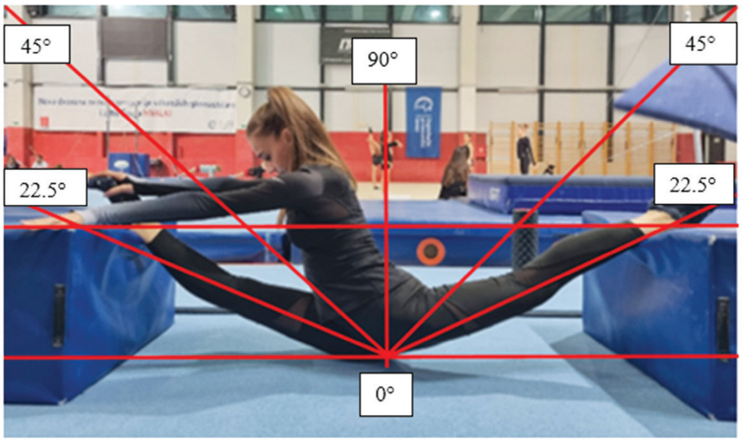

Figure 8. Forward-backward split between two blocks—Test 7.

Results

In Tables 4 and 5 descriptive results of artistic and rhythmic gymnasts are presented for all the flexibility tests.

According to the results presented in Table 6, a statistically significant difference is visible in the active and passive flexibility of the lower limbs between the rhythmic and artistic gymnastics competitors, with an error of p<.05. Therefore, the null (H_0) hypothesis can be rejected and the alternative (H_1) hypothesis accepted. Statistically significant difference is obvious in the following tests: FSWH DOM, FSWOH DOM, SSWH DOM, SSWH NDOM, SSWOH DOM, BSP DOM, BSWH DOM, BEWH NDOM, and FBS DOM. Greater differences between the two groups of gymnasts were obtained

Table 4. Descriptive indicators – artistic gymnastics

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.
FSWH DOM	9	8.11	6	10	1.05
FSWH NDOM	9	7.33	6	9	1.22
FSWOH DOM	9	5.44	4	7	0.88
FSWOH NDOM	9	3.89	2	6	1.27
SSWH DOM	9	8.22	7	9	0.67
SSWH NDOM	9	6.89	5	9	1.17
SSWOH DOM	9	5.67	5	7	0.87
SSWOH NDOM	9	4.11	3	6	1.17
BSP DOM	9	8.33	7	10	1.00
BSP NDOM	9	7.78	6	10	1.20
BSWH DOM	9	4.11	3	6	1.17
BSWH NDOM	9	3.00	2	4	0.71
FBS DOM	9	4.33	1	7	2.12
FBS NDOM	9	2.67	1	6	1.94
TBF	9	10.00	10	10	0.00
SMT	9	9.78	8	10	0.67

Table 5. Descriptive indicators – rhythmic gymnastics

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.
FSWH DOM	9	9.33	8	10	0.71
FSWH NDOM	9	8.22	7	9	0.67
FSWOH DOM	9	7.33	5	9	1.58
FSWOH NDOM	9	4.78	2	7	1.39
SSWH DOM	9	9.78	9	10	0.44
SSWH NDOM	9	8.33	7	9	0.71
SSWOH DOM	9	7.56	6	9	1.13
SSWOH NDOM	9	4.89	4	5	0.33
BSP DOM	9	9.78	9	10	0.44
BSP NDOM	9	8.56	7	10	0.88
BSWH DOM	9	8.33	5	10	1.80
BSWH NDOM	9	6.11	4	10	1.90
FBS DOM	9	8.33	4	10	2.35
FBS NDOM	9	3.67	1	7	2.12
TBF	9	10.00	10	10	0.00
SMT	9	10.00	10	10	0.00

in passive flexibility tests than in active flexibility tests. We can also see that rhythmic gymnasts are more flexible than artistic gymnasts.

Results of Sign test in Table 7 show that there is statistically significant difference between the dominant and non-dominant legs of artistic gymnasts in four tests.

In Table 8 the differences between the dominant and non-dominant legs of rhythmic gymnasts are presented as obtained in seven tests of flexibility, i.e., in four tests of passive and in three tests of active flexibility.

Discussion and conclusion

The purpose of this study was to examine and compare the flexibility and strength characteristics of rhythmic and artistic gymnasts. The tests of passive flexibility showed greater differences compared to the tests of active flexibility, demonstrating that rhythmic gymnasts have greater flexibility than artistic gymnasts. This was expected, as rhythmic gymnastics places much less importance on explosive strength compared to artistic gymnastics, reflecting different physical demands and training approaches. The effect sizes calculated

Table 6. Results of Mann-Whitney U test for independent samples

Variable	Rank Sum Group 1	Rank Sum Group 2	U	Z	p-value	Z adjusted	p-value	Valid N group 1	Valid N group 2	2*1sided exact p	Cohen's d
FSWH DOM	113.00	58.00	13.00	2.38	0.02	2.51	0.01	9	9	0.01*	1.24 (large)
FSWH NDOM	103.00	68.00	23.00	1.50	0.13	1.57	0.12	9	9	0.14	0.85 (medium)
FSWOH DOM	112.50	58.50	13.50	2.34	0.02	2.41	0.02	9	9	0.01*	1.38 (large)
FSWOH NDOM	101.00	70.00	25.00	1.32	0.19	1.36	0.17	9	9	0.19	0.66 (medium)
SSWH DOM	123.00	48.00	3.00	3.27	0.00	3.44	0.00	9	9	0.00*	2.64 (large)
SSWH NDOM	114.00	57.00	12.00	2.47	0.01	2.55	0.01	9	9	0.01*	1.46 (large)
SSWOH DOM	118.00	53.00	8.00	2.83	0.00	2.89	0.00	9	9	0.00*	1.77 (large)
SSWOH NDOM	101.50	69.50	24.50	1.37	0.17	1.57	0.12	9	9	0.16	0.78 (medium)
BSP DOM	117.50	53.50	8.50	2.78	0.01	2.95	0.00	9	9	0.00*	1.65 (large)
BSP NDOM	102.50	68.50	23.50	1.46	0.15	1.51	0.13	9	9	0.14	0.7(medium)
BSWH DOM	124.00	47.00	2.00	3.36	0.00	3.40	0.00	9	9	0.00*	2.53 (large)
BSWH NDOM	124.00	47.00	2.00	3.36	0.00	3.42	0.00	9	9	0.00*	1.73 (large)
FBS DOM	116.50	54.50	9.50	2.69	0.01	2.73	0.01	9	9	0.00*	1.63 (large)
FBS NDOM	98.50	72.50	27.50	1.10	0.27	1.12	0.26	9	9	0.26	0.45 (small)
TBF	85.50	85.50	40.50	-0.04	0.96			9	9		0.00 (small)
SMT	90.00	81.00	36.00	0.35	0.72	0.89	0.37	9	9	0.73	0.63 (medium)

Note. *Significant difference, p<.05; Cohen's d – effect size.

Table 7. Sign test artistic gymnasts' difference between the dominant and non-dominant leg

Pair of variables	No. of non-ties	Percent v < V	Z	p-value
FSWOH DOM & FSWOH NDOM	8	0.00	2.47	0.01*
SSWH DOM & SSWH NDOM	8	0.00	2.47	0.01*
SSWOH DOM & SSWOH NDOM	8	0.00	2.47	0.01*
FBS DOM & FBS NDOM	8	0.00	2.47	0.01*

Note. *Significant difference, p<.05.

Table 8. Sign test rhythmic gymnasts' difference between the dominant and non-dominant leg

Pair of variables	No. of non-ties	Percent v < V	Z	p-value
FSWH DOM & FSWH NDOM	7	0.00	2.27	0.02*
FSWOH DOM & FSWOH NDOM	8	0.00	2.47	0.01*
SSWH DOM & SSWH NDOM	9	0.00	2.67	0.01*
SSWOH DOM & SSWOH NDOM	9	0.00	2.67	0.01*
BSP DOM & BSP NDOM	8	0.00	2.47	0.01*
BSWH DOM & BSWH NDOM	8	0.00	2.47	0.01*
FBS DOM & FBS NDOM	9	0.00	2.67	0.01*

Note. *Significant difference, p<.05.

provide insight into the practical significance of the differences observed between the groups. Here, we discuss the implications of these effect sizes: small, medium and large effect size (from small to large differences between the groups). Overall, the magnitude of these effects underscores the varying degrees of practical significance in the differences between the groups. Large effect sizes highlight substantial differences that are likely to be of high practical importance, while medium effect sizes indicate meaningful differences, and small effect sizes suggest minor differences. These insights can guide future research and decision-making processes. Differences refer predominantly to the dominant leg, which was expected because each gymnastic element is performed on the dominant leg. For example, in rhythmic gymnastics, there are jumps/leaps like stag leap with a ring or back bend of the trunk, split leap with a ring or back bend of the trunk, turning stag leap (with a ring or back bend of the trunk), turning split leap "jete en tournant" (with ring or back bend of the trunk), switch stag or split leap, etc. Jumps that are usually performed in artistic gymnastics on floor and beam are Johnson jump (90°, 180°), split leap, switch leap, switch leap to ring position, straddle pike jump, split jump with turns (180°, 360°, 540°), ring jump, and illusion turn (360°). In both artistic and rhythmic gymnasts there are differences between their dominant and non-dominant legs. According to the results, the gymnasts' levels of active and passive flexibility were higher for their preferred lower limb than for their non-preferred lower limb (Santos, et al., 2015). These results are similar to results in some investigations. The main findings showed that 86.7% of the Portuguese junior gymnasts had high flexibility asymmetry ratings of different magnitudes between their dominant and non-dominant limbs (Batista Santos, et al., 2017). Variations in passive and active flexibility between the non-preferred and preferred lower limbs were seen in all groups, degree of asymmetry decreases as the level of competition increases (Batista, et al., 2019a). The most likely explanation could be that elements are usually performed on the dominant leg. Different impact of stretching on the range of motion was however shown when the volume of the stretching load was asked (Donti, et al., 2022). Stretching should be trained both for active and passive flexibility, also at the beginning of a training session in the dynamic mode and at the end of session in the static mode. According to a number of examined studies, the research conducts some reflections on the different stretching strategies used during the gymnastics training phases (warming up, cooling down), which are helpful in organizing training sessions that result in the best performance (D'Anna & Paloma, 2015). Long static stretching improves range of motion (ROM) but has no detrimental effects on CMJ performance in very young female gymnasts who have undergone flexibility training (Papia, et al., 2018). After six weeks, the static stretch and Mulligan's Long Leg Traction Group 1 (Mulligan concept) showed statistically significant gains in acute changes compared to Group 2 (static stretching) (Karloh, et al., 2010). Also, flexibility is not the same across different ages. While adolescents reacted equally to both higher and lower volumes of stretching load, children showed better results with higher volume of load compared to lower volume of stretching load (Donti, et al., 2022). Depending on the anatomical region tested (lower limbs, upper limbs, or multijoint testing) and the type of flexibility produced (passive or active), flexibility improves across the gymnastics season at various levels of adaptation (Irurtia, et al., 2010). Our study did not seek differences in shoulder flexibility between artistic and rhythmic gymnasts. Shoulder and hip flexibility are the quality that separates elite gymnasts apart from the competition (Donti, et al., 2016). However, this referred to artistic gymnasts. The technical execution score appears to be more influenced by physical fitness at the lower performance level (non-qualifiers) (Donti, et al., 2016). An athlete may not always have good mobility just because they are flexible so understanding the distinctions between mobility and active flexibility is essential for defining functional flexibility (Berisha & Oktay, 2021). Among the many tests conducted, the split, shoulder flexibility, bridge and sit-and-reach tests were the most frequently used ones (Vernetta, et al., 2020). In artistic gymnasts, flexibility and jumping performance improved under both the whole body vibration and static stretching settings, each of which had a unique impact on the variables under investigation (Dallas & Kirialanis, 2013). Although the results obtained show that rhythmic gymnasts were more flexible, i.e., had a greater range of motion than both groups, the question arises whether such a result was a consequence of a different level of maturity (according to Tanner's stage) and delayed puberty and thus bone development (Mandroukas, et al., 2023). This confirms that this stage of maturation has very little influence on the aforementioned abilities in girls who maintained a constant practice of rhythmic gymnastics during the testing period (Haywood, 1980). The small sample size of elite gymnasts meant that we were not able to divide them into distinct age groups. Consequently, this limitation restricts our ability to analyse how developmental stages or maturity levels may have influenced the observed flexibility and strength characteristics. Tringali's research findings indicated a correlation between the COL5A1 CT genotype and both high joint mobility and *genu recurvatum* incidence (Silva, et al., 2019). The research paper showed that there was difference in active and passive flexibility of lower limbs between rhythmic and artistic gymnasts, in favour of rhythmic gymnasts, as well as differences between the dominant and non-dominant lower limb of each gymnast. The differences between the dominant and non-dominant lower limb were smaller in artistic than in rhythmic gymnasts, which did not come as a huge surprise, because flexibility requirements are much higher in rhythmic gymnastics and consequently the way of training that is often mainly focused on working with dominant limb. The coaches can use these results as good guidance for further planning of training and to detect which aspect of flexibility their gymnasts must work on to prevent further development of body asymmetries. Furthermore, there is also a need for further research on body asymmetry occurrences and their influence on performance and incidence of injuries.

Limitation of the study

The authors are aware of the limitations associated with the sample used in this study. Specifically, the small sample size of elite gymnasts limits the ability to generalize the findings beyond top athletes. To address this limitation, future research should include a larger and more diverse sample of gymnasts to allow for findings to be generalized to a broader population, including international competitors, and not just elite athletes.

Furthermore, it would be valuable to conduct international research involving multiple countries. Such studies would provide opportunities for comparing data across different regions and offer a more comprehensive and global perspective on the flexibility and strength characteristics of gymnasts. This approach would help to enhance the understanding of these characteristics across various levels of competition and cultural contexts.

Additionally, future research should explore the evaluation of flexibility measurements through advanced biomechanical analyses using modern technologies. For instance, incorporating motion capture systems, force plates, and other sophisticated measurement tools could provide more detailed and objective data on flexibility and its biomechanical underpinnings. These technologies could help in understanding the mechanisms behind flexibility and in developing more precise and effective training methods for gymnasts.

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