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Hip and shoulder flexibility in novice rhythmic gymnasts and age-matched controls: Inter-limb asymmetry

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Abstract: Rhythmic gymnastics is a sport of asymmetry and lateral preferences, so the main objective of this study was to examine and compare hip and shoulder range of motion (ROM) and inter-limb asymmetry in 44 rhythmic gymnasts (RGs) and 51 age-matched non-athletes (NAs), i.e. controls. The baseline characteristics of 95 female participants, divided into two age-group categories (U8: 6–8 years, N=36; U11: 8–11 years, N=59) were established, as well as their hip (right/left hip flexion, right/left hip extension, right/left hip abduction, in °) and shoulder ROM (right/left shoulder flexion, right/left shoulder extension, in °), and asymmetry index (ASI, in %) was calculated. Significant differences between RGs and NAs were established (the exception is hip and shoulder extension in U8s, p>0.05), with greater ROM values recorded in RGs. Significant age differences were recorded among RGs in hip flexion and left hip abduction (p<0.05), in favor of U11s, and within NAs only in the case of right hip flexion (p=0.017), but in favor of U8s. The presence of asymmetries (ASI>15%), as well as its absence, is established in both RGs and NAs, but statistically significant side-to-side differences were recorded in U8 NAs (shoulder flexion, p=0.044) and U11 NAs (shoulder extension, p=0.057).

Keywords: rhythmic gymnastics, athletes, non-athletes, range of motion, side-to-side differences

1. Introduction

Flexibility is defined as the 'ability to be bent' (lat. flectere – to bend), but within the realms of physical education, sports medicine, and health sciences, so-called normal flexibility is commonly understood as the range of motion (ROM) achievable in a joint or set of joints [1]. To certain individuals, flexibility represents the capability to move a particular joint or a sequence of joints seamlessly and effortlessly through a ROM without any limitations or discomfort [2]. Broadly, flexibility refers to the maximal physiological range achievable in a specific joint movement, which is contingent upon both muscular elasticity and joint capacity [3], i.e., flexibility implies a set of capabilities closely related to each other, such as joint mobility, muscle elasticity and stretching capacity [4]. What stands out is that flexibility does not exist as a general characteristic but is specific to a particular joint [5], which means that adequate ROM in the hip does not ensure adequate ROM in the shoulder; similarly, sufficient ROM in one hip may not mean sufficient ROM in the other hip, i.e., this motor skill can be asymmetrically developed because it depends on the degree of the use of a specific joint [1]. Additionally, flexibility varies depending on the type of sport. Moreover, specific patterns of flexibility are related to frequent or unique joint movements even among sports groups. Athletes in certain sports require a high ROM in almost every single joint in order to execute certain movements or acquire specific static or dynamic positions [6].

In the realm of sports, rhythmic gymnastics (RG) involves a curated selection of exercises aimed at fostering overall balanced and harmonious physical development. Nevertheless, it stands as a competitive discipline characterized by the early and unilateral specialization of movements [7] that due to its aesthetic and technical prerequisites this sport places significant demands on athletes, necessitating a high level of motor skills, particularly in areas such as flexibility, agility (in terms of coordination abilities), jumping prowess, and overall endurance [8]. RG is rich in movements that require large, sometimes extreme amplitudes and mobility of all of the joints (mostly hip joints), whether the rotations, balances or jumps as fundamental body elements/difficulties [9], or pre-acrobatic elements, full body waves, dance steps, etc., making a flexibility a decisive motor quality in performance – the main reason for finding greater ROMs in rhythmic gymnasts (RGs) [10]. That is why RGs are characterized by their flexible joints and compliant muscles [11], and gymnast who lacks flexibility in a joint linked to the execution of a particular movement will increase the risk of injury by having to use other compensatory mechanisms – an induced uncoordinated movements and low ROM significantly reduce mechanical efficiency and lead to poorer execution of technique and a higher risk of injury [12]. Furthermore, there are point penalties for this reduced effectiveness in comparison to the established model, as stated by Code of Points [13].

During the training, most RGs perform positions and movements that involve excessive use of certain muscle groups and include unilateral flexion in the hip joint, which causes functional muscle imbalance [9]. Also, it is a sport that requires handling of various apparatuses (ball, hoop, rope, ribbon, and clubs), most of which are handled with one hand (usually the dominant/skillful one), and given the variety of body difficulties (jumps, balances, and rotations), most of which are accomplished by always having one leg supporting and the other one free [14]. Due to all this, RG falls under the category of asymmetric sports.

Based on the RG Code of Points [13] and the previously stated information, it is evident that RG is a sport that calls for extreme flexibility of high quality in all joints, particularly the spine, hips, and shoulders, as well as asymmetry in movement. Therefore, the necessity of addressing this issue, i.e. assessing the active flexibility of hips and shoulders in novice RGs, comparison with their non-athletic peers (NAs), as well as testing side-to-side differences, i.e., potential inter-limb asymmetry, is evident.

2. Materials and Methods

2.1. Study Participants

An analysis program G*Power 3.1 was used to determine the sample size. An effect size (d) of 1.0, an alpha level of 0.05, and a power of 80% were assumed, so the estimated total sample size was 17 study participants per group. A convenient sample of 95 female participants, aged 6 to 11, whose parents gave written consent after being informed about the research and its scientific values and benefits, participated in this cross-sectional study: 44 national-level RGs (group competitors, with external training-load of 3 h/week and sports experience from one to five years) and 51 NAs (controls, girls with sporadic athletic involvement and physical education lessons only), who are relatively equal in terms of baseline/demographic characteristics (Table 1) (t-test [1] results indicate the absence of statistically significant differences between these two subsamples). Based on the age, the study participants were divided into two group categories: U8 – from 6.0 to 7.99 years of age (RGs=17, NAs=19) and U11 – from 8.0 to 10.99 years of age (RGs=27, NAs=32).

[1] Apart from the comparison of the flexibility of RGs and NAs, both subsamples were compared in terms of baseline characteristics. But, since it was not the main goal of this research, the results of the t-test are not presented here.

Table 1. Study participants' baseline characteristics.

Subsamples		Variables	Age (yrs)	Height (cm)	Weight (kg)	BMI (kg/m²)
RGs (N=44)	**U8 (n=17)**	*Mean±SD*	6.59±0.59	123.21±6.09	22.65±4.24	14.78±1.63
		Min – Max	6.01 – 7.73	112.4 – 133.0	13.0 – 30.0	10.29 – 17.19
		K-S (Sig.)	.599	.973	.998	.604
	U11 (n=27)	*Mean±SD*	9.34±1.03	137.5±10.85	30.91±6.23	16.19±1.53
		Min – Max	8.06 – 10.95	120.0 – 156.4	20.5 – 44.0	14.2 – 19.49
		K-S (Sig.)	.445	.680	.793	.863
NAs (N=51)	**U8 (n=19)**	*Mean±SD*	7.19±0.67	126.21±7.36	24.82±3.93	15.49±1.46
		Min – Max	6.03 – 7.97	112.0 – 136.0	16.0 – 31.0	12.76 – 18.44
		K-S (Sig.)	.484	.352	.388	.980
	U11 (n=32)	*Mean±SD*	8.71±0.66	134.9±7.82	30.73±7.1	16.73±2.68
		Min – Max	8.04 – 10.37	120.7 – 160.0	20.0 – 51.0	12.22 – 22.57
		K-S (Sig.)	.159	.179	.319	.992

Legend: n, N– number of study participants, **RGs–** rhythmic gymnasts, **NAs–** non-athletes, **U8–** participants under 8 years of age, **U11–** participants under 11 (and over 8 years of age), **Mean–** average value, **SD–** standard deviation, **Min–** minimum, **Max–** maximum, **K-S–** Kolmogorov-Smirnov test, **Sig.–** significance, **BMI–** body mass index, **yrs–** years.

2.2. Ethical Considerations

The study protocol was approved by the local ethics committee (No. 04-298/2, from March 5th, 2024), and the testing was performed in accordance with the ethical standards of the Helsinki Declaration [15]. Consent was given by the Gymnastics Federations and Expert committees for RG, club coaches, primary school, physical education teachers, and by RGs' and NAs' parents.

2.3. Measures and Procedures

All the measurements were taken by the authors in optimal climatic conditions, with the participants in their underwear, and according to the methods proposed by Eston et al. [16]. By interviewing the participants we collected the data on their age, i.e., date of birth (Age, in years), whereas their body height (Height, in 0.1 cm) was determined by Martin's anthropometer. The following body composition parameters, such as body mass (Weight, in 0.1 kg) and body mass index (BMI, in 0.1 kg/m2), were assessed with a tetrapolar bioimpedance device – Omron BF511 (Kyoto, Japan), after entering the data on participants' age, gender and body height. By means of the VUB-goniometer (Vrije Universiteit Brussel, Belgium), after a 20-minute dynamic warm-up session and a 3-minute rest interval, the participants' bilateral joints unassisted flexibility was evaluated, i.e., ROMs in right and left hip (flexion, extension and abduction, in ° [17] (p. 147)) – HFlex-R/L, HExt-R/L and HAbd-R/L, respectively, as well as the ROMs in right and left shoulder (flexion and extension, in ° [17] (p. 139)) – SFlex-R/L and SExt-R/L, respectively, in the laying positions supine, prone or sideways. Measurements were performed by an experienced examiner, first on the left and then on the right limb. To identify possible lateral asymmetries, i.e., inter-limb imbalances, the asymmetry index (ASI, in 0.1%) was calculated (Equation 1):

$$ASI = [(SLL – LSL) / SLL] \times 100\%, \quad (1)$$

where SLL is skillful limb, and LSL is less skillful limb [18]. A limit of 15% of bilateral difference was established as the maximum value for a normal difference, i.e. no lateral asymmetry between SLL and LSL [19].

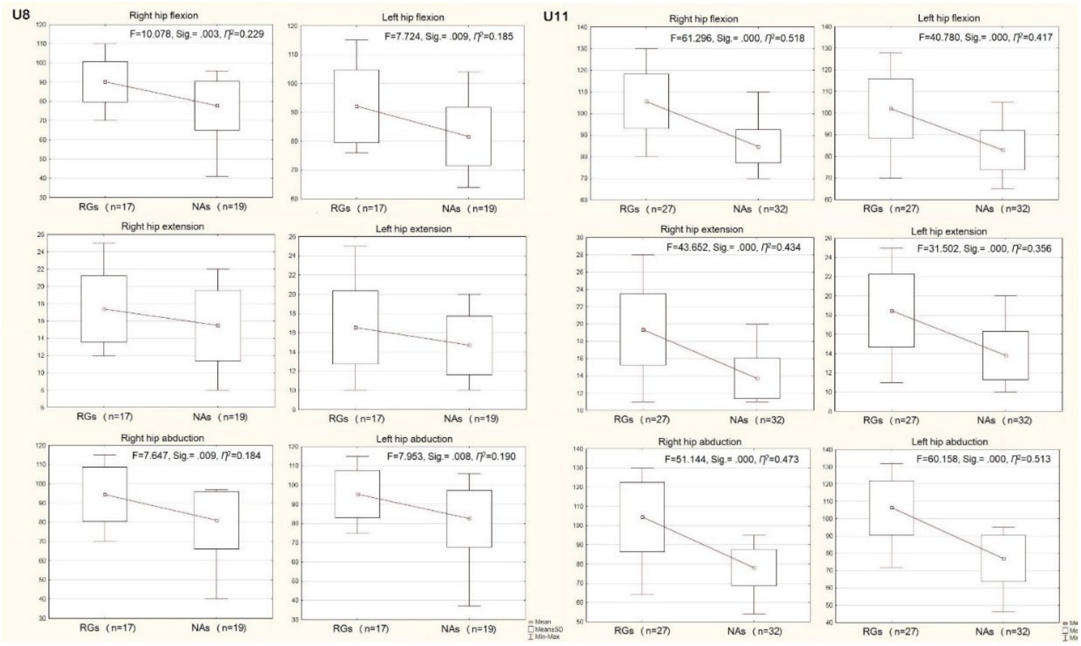
2.4. Statistical Analysis

The descriptive statistics [average value (Mean), standard deviation (SD), minimum (Min), maximum (Max)] were summarized for all variables and for each of two samples, i.e. four subsamples. Prior to the statistical analysis, the distribution of raw data sets was assessed using the Kolmogorov-Smirnov test (K-S) and demonstrated that all data had a normal distribution ($p>0.05$). In order to determine the level of statistical significance of the differences in the recorded hip and shoulder ROMs of RGs and NAs, a one-way ANOVA was applied for samples comparison, while paired t-test was used to detect side-to-side differences. The effect sizes of each variable were tested using eta squared (η^2) between groups (0.01 = small effect, 0.06 = moderate effect, and 0.14 = large effect [20]). The level of significance was set at $p<0.05$, and the data were analysed using the Statistical Package for the Social Sciences, version 26.0 (IBM SPSS 26.0, SPSS Inc., Chicago, USA).

3. Results and Discussion

In RG, flexibility is closely related to technique, because many of the technical elements that RGs must execute in their routines are basically flexibility movements [21], i.e., the capacity for flexibility is present at all times in gymnast's work (it is essential for the execution of all characteristic body elements and apparatus handling), thus enabling the most diverse and spectacular movements [4]. Presently, strong flexibility, particularly hypermobility, forms the framework of fundamental RG movements such as jumps, balances, rotations, and pre-acrobatic elements. This heightened level of flexibility contributes to an elevated technical proficiency, thereby leading to enhanced performance outcomes in RG competitions [22]. On the other hand, insufficient flexibility impairs performance and makes it more challenging to enhance the technique, foster expressiveness and exhibit the lightness of movements – all of which are crucial aspects of this sport [23]. According to some authors [24, 25], RGs should exhibit flexible joints, in particular hips, shoulders and spine.

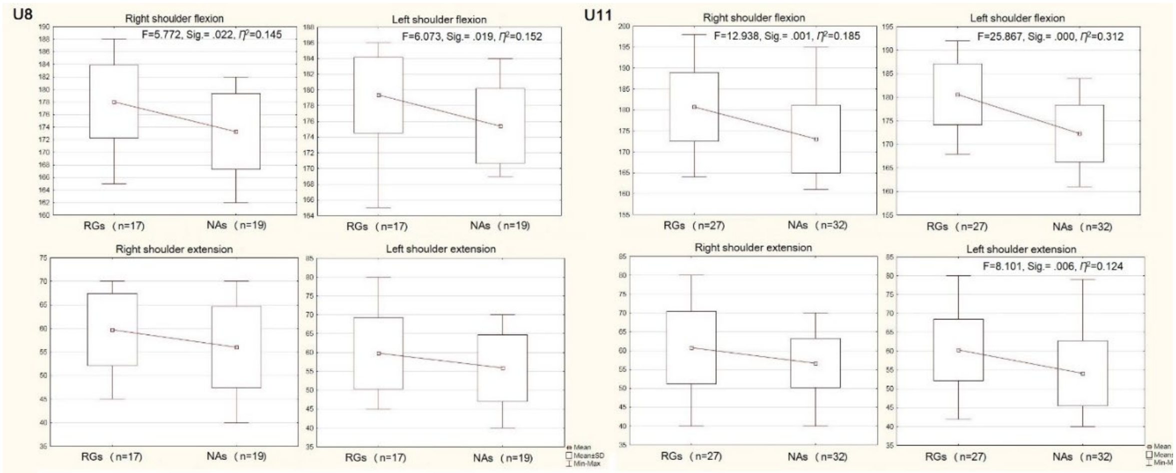
Figure 1 shows the values of hip joint flexibility recorded in each subsample and age group. What is noticeable are the expected differences between RGs and NAs, with higher hip flexibility values recorded in the subsample of RGs, which was previously established [26]. Namely, in the U8 age group, RGs have statistically greater values than their NA peers in case of hip flexion and hip abduction ($p<0.01$); in U11 age group those differences are more pronounced and present in all of the six hip flexibility variables ($p<0.001$). However, despite the fact that joint mobility in children is inversely related with age, with the younger children producing greater joint mobility than the older ones [27], the age differences are present and they are in favor of older participants, whether RGs or NAs – higher values of hip ROM are recorded in U11 age group; however, even the U8 RGs have greater hip ROM than the U11 NAs (see Figure 1). When younger and older RGs compared, statistically significant differences can be noted in the case of hip flexion with large and moderate effects, respectively (HFlex-R: F=17.784, Sig.=0.000, η^2=0.297, HFlex-L: F=5.772, Sig.=0.021, η^2=0.121) and left hip abduction (HAbd-L: F=6.143, Sig.=0.017, η^2=0.128), but with moderate effect, while those in case of right hip abduction are close to significance (HAbd-R: F=3.725, Sig.=0.060, η^2=0.081). The established differences are in favor of the older RGs, the ones with longer sports experience, which is consistent with previous findings [28]. Between younger and older NAs statistically significant differences with moderate effect are only established in case of the right hip flexion (F=6.132, Sig.=0.017, η^2=0.111), and very close to significance differences were found in case of the right hip extension (F=3.884, Sig.=0.054, η^2=0.073). These results indicate that RG is a sport discipline that has a significant impact on the level of hip joint flexibility, which is in accordance with previous results [25].



(**a**) (**b**)

Figure 1. Hip flexibility (in °) in RGs and NAs – one-way ANOVA and eta squared values: (**a**) in U8s; (**b**) in U11s.

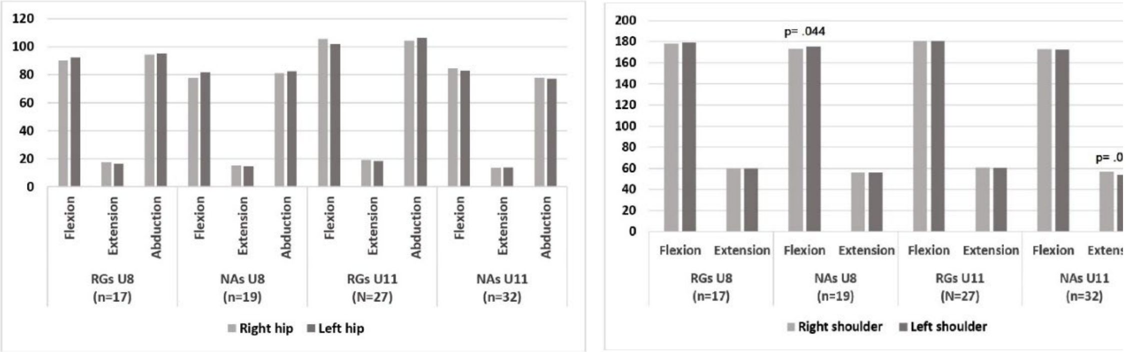
The anatomy of the shoulder complex permits a great deal of movement in both sports and daily life, and inadequate ROM in this joint can predispose athletes and others to shoulder injuries [29]. Figure 2 displays the shoulder flexibility values observed in each of subsamples and age groups. In shoulder flexion, notable large-effect differences are evident between RGs and NAs for both the right and left limbs: in the U8 age group, the significance is $p<0.05$, whereas in the U11s this significance is even more pronounced ($p<0.001$), with recorded values being higher in the RG subsample. Regarding shoulder extension, moderate-effect differences detected solely in the left limb and exclusively within the U11 age group ($p=0.006$), while for the right limb, this difference approaches significance ($p=0.059$). This observation could suggest the long-term impact of RG training on this shoulder movement, which is infrequently utilized in everyday activities. Namely, there are generally six movements of a shoulder (flexion, extension, abduction, adduction, external, and internal rotation) and each movement plays a distinct role in facilitating various daily tasks. For instance, tasks such as reaching up to high shelves or washing hair necessitate a combination of flexion and adduction, while accessing items in the back pocket requires extension, internal rotation and adduction. Similarly, activities like combing hair require external rotation, flexion, and abduction [30]. Comparison of different age groups indicated absence of statistically significant age differences in both RGs and NAs; the exception is left shoulder flexion of the U8 and the U11 NAs which is close to statistically significant differences ($p=0.063$). However, age differences do exist in shoulder flexibility and slightly greater ROM values are recorded mostly in the older participants, which is not consistent with previous findings [31].



(**a**) (**b**)

Figure 2. Shoulder flexibility (in °) in RGs and NAs – one-way ANOVA and eta squared values: (**a**) in U8s; (**b**) in U11s.

There is a natural difference between sides, and the rationale for these discrepancy is related to usage [32]. Therefore, it is recommended paying attention to the importance of mastering the right and left extremity equally and successfully and to symmetrical training of the athlete's abilities [33], because versatile, i.e. dexterous athletes have a significant advantage over asymmetrical ones [34]. Despite the fact that RG attempts to train the entire body bilaterally, in order to attain the highest level of efficiency training entails performing repetitive motor actions mostly with the preferred side. This ultimately characterizes the practice as unilateral [35], and it may still result in muscular imbalances [23]. In this study, the inter-limb disparities are observed, and are noted (see Figure 3), but they are not statistically significant in case of hip joint flexibility, neither in RGs nor NAs; in shoulder flexibility statistically significant side-to-side differences were recorded only among the U8 NAs (SFlex, t=-2.170, df=18, p=0.044) and the U11 NAs (SExt, t=1.980, df=31, p=0.057). Still, differences between right and left sides do exist, even though the majority of participants have hip and shoulder ASIs in the range of normal values, i.e. from 0% to 15% (Table 2). Namely, RG is known as sport of functional, i.e. motor asymmetries [23], and even though, while training novice RGs, coaches insist that they use both sides of the body equally, with the increase in the length of their sports experience in most of RGs the 'stronger' and 'weaker' body sides are distinguished, i.e., preferred (skillful) and non-preferred (less skillful) leg/arm [36]. Hence, RGs are compelled to consistently deliver their best and safest performance, particularly in terms of execution posture, during competitions. This often entails favoring one side of the body, i.e., a preferred leg (typically the more stable/skillful leg, utilized as a support when performing rotations and balances, or the one with greater explosive strength for take-offs when performing jumps), or a favored (more skillful) hand for apparatus handling or executing pre-acrobatic elements with one-hand support. This side preference is of great importance for group competitors due to necessity of accomplishing team symmetry, equality, homogeneity and visual harmony in choreography movements (body difficulties and apparatus handling), the absence of which would impair the artistic score [13], while for RGs dedicated to individual competition this laterality seems to be indifferent. However, what RG coaches and gymnasts overlook is that ambidexterity directly affects sports performance [37], and side inequality could affect RGs' spine postural status. To be specific, during their training, most of RGs are forced to break their posture by practicing certain stances, by performing positions and movements that involve excessive use of certain muscle groups, and include unilateral flexion/extension/abduction in hip joint, which causes functional muscle imbalance and can potentially lead to scoliosis due to asymmetric loading of the spine [9].



(a) (b)

Figure 3. Side-to-side differences – paired samples t-test: (**a**) comparison of the recorded values of participants' hip flexibility (in °); (**b**) comparison of the recorded values of participants' shoulder flexibility (in °).

Table 2. Prevalence of hip and shoulder flexibility inter-limb asymmetries in RGs and NAs.

Variables	ASI	RGs (N=44)				NAs (N=51)			
		U8 (n=17)		U11 (n=27)		U8 (n=19)		U11 (n=32)	
		f	%	f	%	f	%	f	%
Hip flexion	*0%*	1	5.88	1	3.7	1	5.26	1	3.12
	≤15%	16	94.12	22	81.48	14	73.68	30	93.75
	>15%	0	0	4	14.82	4	21.06	1	3.13
Hip extension	*0%*	1	5.88	2	7.41	3	15.79	5	15.63
	≤15%	11	64.71	13	48.15	9	47.37	14	43.75
	>15%	5	29.41	12	44.44	7	36.84	13	40.62
Hip abduction	*0%*	2	11.76	1	3.7	3	15.79	2	6.25
	≤15%	15	88.24	19	70.37	13	68.42	27	84.38
	>15%	0	0	**7**	25.93	3	15.79	3	9.37
Shoulder flexion	*0%*	4	23.53	2	7.41	3	15.79	4	12.5
	≤15%	13	76.47	25	92.59	16	84.21	27	84.38
	>15%	0	0	0	0	0	0	1	3.12
Shoulder extension	*0%*	3	17.65	5	18.52	3	15.79	5	15.62
	≤15%	12	70.59	18	66.66	11	57.89	17	53.13
	>15%	2	11.76	4	14.82	5	26.32	10	31.25

Legend: n, N– number of study participants, **RGs**– rhythmic gymnasts, **NAs**– non-athletes, **U8**– participants under 8 years of age, **U11**– participants under 11 (and over 8 years of age), **ASI**– asymmetry index, **0%**– absolute absence of lateral asymmetry, **≤15%**– absence of lateral asymmetry, **>15%**– presence of lateral asymmetry, **f**– frequency.

Asymmetry index is commonly used in the field of sport science to quantify neuromuscular deficits between limbs [38] which may predispose injury [the weaker/less-skillful limb is typically predisposed to injury, according to Hewit et al. [39]. Usually, this index is obtained by comparing dominant and non-dominant limb, but there are some authors who concluded that perceived limb dominance may not be the best predictor of limb neuromuscular performance [38], and that the comparison between more and less skillful limb is better option for detecting inter-limb asymmetries [18]. Obtained ASI values for each subsample and age group are presented in Table 3 and, on average, they indicate absence of inter-limb disparities, i.e., ASI≤15% [19]. Nevertheless, differences in ASI between RGs and NAs within the same age group are noted. In the U8 age group greater values of all five ASIs were recorded in NAs. Still, statistically significant difference with large effect was noted only in the case of ASI_{HFlex} (F=9.174, Sig.=0.005, η^2=0.212). In the U11 age group, higher asymmetry indices for hip flexibility were observed among RGs, whereas for shoulder flexibility, greater values were noted among NAs. Only in case of shoulder flexion ASI is very close to statistical significance of moderate effect (ASI_{SFlex}: F=3.860, Sig.=0.054, η^2=0.063). Additionally, age disparities are evident, albeit solely concerning the hip joint: among RGs, with large and moderate effect, respectively, in ASI_{HFlex} (F=7.518, Sig.=0.009, η^2=0.152) and ASI_{HAbd} (F=4.317, Sig.=0.044, η^2=0.093), and among NAs in ASI_{HFlex} (F=5.060, Sig.=0.029, η^2=0.094) with moderate effect. The obtained minimum and maximum values (Table 3) indicate presence of both total side-to-side equality (ASI=0%) and large inter-limb asymmetries (ASI>15%), especially among older age group of participants. In fact, most of the participants, mainly the older ones, have ASIs near the upper limit of cut-off point for asymmetry, which might, or might not, transfer to asymmetry in the following training years in case of RGs (comparison of high-level RGs of longer sport experience length with novices would have clarify this dilemma).

Table 3. Asymmetry index of study participants' hip and shoulder flexibility.

Variables	**Subsamples**	**RGs (N=44)**		**NAs (N=51)**	
		U8 (n=17)	**U11 (n=27)**	**U8 (n=19)**	**U11 (n=32)**
ASI_{HFlex} (in %)	*Mean±SD*	3.79±3.57	8.11±5.84‡	10.98±9.18§†	6.76±4.17
	Min – Max	0.0 – 13.46	0.0 – 21.05	0.0 – 35.94	0.0 – 19.51
	K-S (Sig.)	.351	.843	.372	.771
ASI_{HExt} (in %)	*Mean±SD*	12.5±9.72	14.17±9.45	13.70±11.77	12.92±8.97
	Min – Max	0.0 – 40.0	0.0 – 31.82	0.0 – 41.18	0.0 – 26.67
	K-S (Sig.)	.348	.436	.860	.353
ASI_{HAbd} (in %)	*Mean±SD*	5.11±3.91	8.89±6.81†	8.04±6.05	8.17±6.94
	Min – Max	0.0 – 14.46	0.0 – 23.08	0.0 – 17.53	0.0 – 26.98
	K-S (Sig.)	.790	.271	.889	.750
ASI_{SFlex} (in %)	*Mean±SD*	1.49±1.62	1.62±1.25	2.04±1.71	2.85±3.04†
	Min – Max	0.0 – 5.56	0.0 – 4.64	0.0 – 5.03	0.0 – 15.39
	K-S (Sig.)	.307	.099	.676	.207
ASI_{SExt} (in %)	*Mean±SD*	9.02±6.11	7.32±6.37	10.37±5.95	10.53±7.46
	Min – Max	0.0 – 18.18	0.0 – 23.75	0.0 – 20.0	0.0 – 24.05
	K-S (Sig.)	.921	.427	.875	.728

Legend: **n, N**– number of study participants, **RGs**– rhythmic gymnasts, **NAs**– non-athletes, **U8**– participants under 8 years of age, **U11**– participants under 11 (and over 8 years of age), **Mean**– average value, **SD**– standard deviation, **Min**– minimum, **Max**– maximum, **K-S**– Kolmogorov-Smirnov test, **Sig.**– significance, **ASI_{HFlex}**– hip flexion asymmetry index, **ASI_{HExt}**– hip extension asymmetry index, **ASI_{HAbd}**– hip abduction asymmetry index, **ASI_{SFlex}**– shoulder flexion asymmetry index, **ASI_{SExt}**– shoulder extension asymmetry index.

ANOVA (**RGs vs. NAs**, within same age-groups): § significant at level p<0.01

ANOVA (**U8 vs. U11**, within RGs, i.e. NAs): † significant at level p<0.05, ‡ significant at level p<0.01

According to the authors' observation, the asymmetry index utilized in the study presents certain drawbacks, as it can yield identical values for significantly different ranges. For example, the ASI registers a value of 15.39% for a mere 3° disparity in ROM between right and left hip extension, and likewise for a 30° difference in ROM between right and left shoulder flexion. Additionally, a side-to-side difference of 3° in hip extension ROM results in an ASI of 20%, which is equivalent to a 10° difference in ROM between right and left shoulder extension. Based on the mentioned, one of this study limitations would be the failure to employ the angular asymmetry index, which is a recommended measure for capturing symmetry in angular data [40]. Another limitation is the omission of arm and leg dominance, which might be of great importance due to fact that lower ROM in the dominant side could be sign of degenerative or ligamentous changes [30], and on the other hand there were some findings in which was indicated that participants' reports of preferred footedness were not associated with bilateral differences in the functional characteristics [41]. However, since 90% of people are right-handed [31] and given that in the lower-limb predominance between 60% and 82% of people exhibit right leg dominance [42], it is plausible to presume that the vast majority of participants were in that group. Nevertheless, knowing the arm and leg dominance of individuals would have strengthened the statistical differences even further. From a scientific standpoint, a prospective at least one-year long cohort research would have been more reliable for identifying the impact of age group and RG training on hip and shoulder flexibility, and due to the cross-sectional study design some results should be interpreted with caution. Also, RG top-level competitors would allow better insight into this topic, especially the one concerning the functional asymmetry. Finally, many hip and shoulder movements were not measured, because of the time constraints on the clinic testing.

4. Conclusions

Apart from the great importance in achieving success in RG and various other sports disciplines, well-developed flexibility has an exceptional contribution in the function of health prevention – it plays a crucial role in preventing injuries caused by overstretching of body segments or individual muscle groups, and individuals with higher level of flexibility also tend to exhibit greater energy and mechanical efficiency in movement. Furthermore, age-related declines in flexibility can impact normal daily functioning, with upper body flexibility being essential for tasks like dressing and reaching for objects, and lower body flexibility crucial for maintaining normal walking patterns and activities involving bending and reaching. Consequently, improved flexibility not only enhances quality of life and physical performance but also reduces the risk of injuries. This study revealed significant age-by-activity interaction for both hip and shoulder joint active flexibility in RGs and NAs, with greater ROM values observed in RGs and in older participants. Namely, RG represents a specific type of flexibility training by encompassing a planned, deliberate, and regular program of exercises that can progressively increase the useable ROM of a joint or set of joints over time, thereby allowing RGs to optimize flexibility. Even though RG is known as a sport of asymmetry, inter-limb asymmetry was found to be more pronounced in NAs (except for the hip flexion and hip abduction), which means that NAs do not have the same degree of bilateral use of hip and shoulder joint, and that efforts greater than those provided by activities of daily living or light activities are needed, i.e., incorporating flexibility exercises into broader scope of exercise regimens is recommended. Also, this presence of side-to-side differences in RGs indicates that RG coaches should have to pay more attention to the symmetrical involvement of the left and right sides of the RGs' body.

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