

# POSTURAL STATUS OF THE SPINAL COLUMN IN YOUNG RHYTHMIC GYMNASTS

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## SUMMARY

Numerous studies highlight the beneficial effects of physical activity on children's and adolescents' health in all areas, and it is commonly known that regular sports participation enhances motor skills and has a major impact on physical development and posture. However, asymmetric physical exercises, unique to a certain sport, such as rhythmic gymnastics (RG), can cause aberrant curvatures of the spine, particularly during times of rapid growth and development. The main research objective is to determine the type and prevalence of postural disorders of the spine in sagittal and frontal plane in 48 young female rhythmic gymnasts (RGs), aged 6 to 18, as well as to examine the differences between 25 juvenile and 23 adolescent RGs. Their baseline characteristics (age, body height and mass, and body mass index) were established, as well as their spine curvature status (kyphosis, lordosis, and thoracic and lumbar scoliosis, in °) by means of the SpinalMouse® device. The data were analyzed (descriptive statistics, Kolmogorov-Smirnov test, ANOVA, Chi-square test) using SPSS 21.0. Research results showed that large percentage of RGs had postural disorders in the sagittal (64.6%), and also in the frontal plane (77.1%), noting that postural disorders are more prevalent in juvenile RGs (72% and 76% in the sagittal and the frontal plane, respectively), and flat back is a common spinal posture disorder in RGs. When comparing the sizes of the spinal column curvatures of juvenile and adolescent RGs, statistically significant differences exist only when it comes to kyphosis ( $p=0.037$ ), and that "in favor" of the older subsample.

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Such results (presence of lordotic, scoliotic and minor presence of kyphotic posture) are not surprising if we take into account the technical and tactical requirements of RG which belongs to a group of asymmetric sports- RGs have stronger extensors than trunk flexors which leads to absence of kyphotic and an increase of lordotic posture; also, RG is a sport of asymmetric spine loading because of unilateral hip flexibility in various conditions, which explains the large prevalence of scoliotic posture among RGs.

**Keywords:** rhythmic gymnastics, functional asymmetry, kyphosis, lordosis, scoliosis

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## INTRODUCTION

The physiological curvature of the spinal column is gradually formed in the earliest stages of posturogenesis, and the degree of curvature of the spine depends on many factors, such as gender, lifestyle, type and level of physical activity, etc. Physical activity is very important and desirable in the development of children and their musculoskeletal system (Jandrić, 2015), and it affects ossification processes and muscle strength, and is one of the important factors that affect posture (Lichota et al., 2011). A large number of studies emphasize the positive impact of physical activity in children and adolescents on all aspects of health (Weinsier et al., 1998; Strong et al., 2005; Ischander et al., 2007; Menschik et al., 2008; Tittlbach et al., 2011), and it is well known that participation in regular sports activities shapes the character of a young person, improves motor and coordination abilities and significantly affects physical development and good posture (Grabara, 2012). Therefore, sport is recommended as a preventive measure, but also as one of the options in the multidisciplinary treatment of most disorders of the musculoskeletal system in children. However, sport is also considered a possible causative factor for the appearance of postural disorders, especially scoliosis (Jandrić, 2015), because in certain studies and literature we can find results that speak of changes in the region of the spinal column in athletes of various sports that involve large rotations, such as artistic and rhythmic gymnastics, swimming, wrestling, javelin throwing, ballet (Tanchev et al., 2000; Wood, 2002; Slawinska et al., 2006; Modi et al., 2008; Grabara & Hadzik, 2009a, 2009b; Longworth et al., 2014). Namely, asymmetric physical exercises, unique to a certain sport, can lead to the appearance of abnormal curvatures of the spine, especially during the period of intensive growth and development, and research shows that in many sports, especially asymmetric ones, there is a disturbance of spine static, trunk asymmetry, as well as disproportion of muscle mass in athletes (Hawrylak et al., 2001; Grabara & Hadzik, 2009a, 2009b). Some postural disorders are more common in certain sports fields, so it is assumed that the specific demands of the sport and training loads, which occur during the execution of

technical elements, as well as their prolonged repetition, influenced the development of those postural disorders. In this group of high-risk sports for the occurrence of postural disorders, there are sports that are characterized by the performance of movements of extreme amplitudes in all major joints, and especially in the area of the spinal column: rhythmic gymnastics, figure skating, dance (Micheli, 1983; Cirillo & Jackson, 1985; Swärd et al., 1990).

Rhythmic gymnastics (RG) as a sports discipline uses a series of specially selected exercises that contribute to the balanced and harmonious development of the organism as a whole. However, considering that it involves the use of different apparatuses (ball, hoop, rope, ribbon and clubs), which are mostly one-hand handled (with the dominant one), and considering that there are plenty of body difficulties (jumps/leaps, rotations/turns/pivots, balances) which are mostly realized by always having one leg supporting and the other one free (Purenović-Ivanović et al., 2023), RG belongs to asymmetric sports, so it is not surprising that the prevalence of scoliosis is greater in those who practice this sport discipline (Tanchev et al., 2000). For the aforementioned reasons, the problem of this research is to determine the type and prevalence of postural disorders of the spine in sagittal and frontal plane in young rhythmic gymnasts (RGs), as well as to examine the differences between juvenile and adolescent RGs.

## **METHODS**

### **Study participants**

The study included 48 national-level female RGs ("B" and "C" program individual and/or group competitors), aged 6 to 18 years: 25 juvenile RGs (up to 10 years of age) and 23 adolescent RGs (10 years and up older), and only those respondents (over 18 years old) who previously accepted voluntary participation in this research, i.e. those minor respondents whose parents gave written consent for their child's participation.

### **Measures and procedures**

The testing was performed in accordance with the ethical standards of the Helsinki Declaration (WMA, 2013). All the measurements were taken by the authors in optimal climatic conditions, with the participants in their underwear. By interviewing the participants we collected the data on their age (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/m<sup>2</sup>) 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 SpinalMouse®

device (Idiag, Fehraltdorf, Switerland) the participants' spinal posture, i.e. size of kyphotic, lordotic, thoracic scoliotic and lumbar scoliotic curvature of the spinal column (KYPH, LORD, TSCOL and LSCOL, respectively, in °), in the "standing" mode, was established.

### Statistical analyses

The descriptive statistics [average value (Mean), standard deviation (SD), minimum (Min), maximum (Max)] were summarized for all variables and for each of two subsamples, as well as for the entirety of the sample. Normality was tested using the one-sample Kolmogorov-Smirnov test (K-S). In order to determine the level of statistical significance of the differences in the recorded sizes of spinal column curvatures in the sagittal and frontal plane of juvenile and adolescent RGs, an univariate analysis of variance (ANOVA) was applied, and *eta* value was determined to establish how pronounced these differences were. For comparison of the spinal disorders prevalence of juvenile and adolescent RGs, the Chi-square test was applied. The level of significance was set at  $p < 0.05$ , and the data were analyzed using the Statistical Package for the Social Sciences, version 21.0 (IBM SPSS 21.0, SPSS Inc, Chicago, USA).

## RESULTS AND DISCUSSION

Table 1 provides a summary of the descriptive statistics for the baseline characteristics of the study participants, for each subsample separately as well as for the entirety of the sample. Upon reviewing the table and considering the BMI cut-off points for girls of different ages (CDC, 2000), on average, both subsamples fall within the normal weight range. Among juvenile RGs, 20 of them (80%) have a normal BMI value, three (12%) have a high BMI value, and two (8%) have a low, i.e. very high BMI value. The situation among adolescent RGs is better– only one has a BMI above the recommended values for girls of that age. In a study carried out even 12 years ago on a sample of top-level adolescent RGs (Radaš & Trošt Bobić, 2011), almost the same BMI values were recorded, which amounted to  $17.65 \pm 2.09$  kg/m<sup>2</sup>, although, on average, the entire sample was one year older ( $13.33 \pm 3.27$  years), while in the research Opala-Berdzik et al. (2021) lower BMI values in a sample of 10 national-level RGs ( $13.2 \pm 9.0$  kg/m<sup>2</sup>) were recorded, but the mean values are on the margin of the lower normal values, which shows that the results recorded on the total sample are in accordance with the previous literature. However, in the already mentioned research (Radaš & Trošt Bobić, 2011) slightly different mean values of the body height were recorded ( $156.37 \pm 14.26$  cm) compared to this study ( $149.71 \pm 10.00$  cm), but not in body mass ( $44.27 \pm 12.61$  kg vs.  $39.64 \pm 9.43$  kg). Upon reviewing the results of a study carried out more than 20 years ago (Tanchev et al., 2000), it can be noted that BMI

values do not differ greatly ( $17.99 \pm 1.79$  kg/m<sup>2</sup>), while body mass values were somewhat lesser ( $36.32 \pm 6.89$  kg) in a sample of RGs of the same age (as adolescent RGs in this study).

**Table 1.** Baseline characteristics of the study participants

Samples	Variables	Age (yrs)	Height (cm)	Weight (kg)	BMI (kg/m <sup>2</sup> )
Juvenile RGs (n=25)	Mean±SD	8.07±1.23	129.44±9.45	27.36±5.76	16.20±2.16
	Min – Max	5.43 – 9.99	113.5 – 153.4	17.9 – 41.3	13.21 – 22.84
Adolescent RGs (n=23)	Mean±SD	12.13±2.52	149.71±10.00	39.64±9.43	17.47±2.58
	Min – Max	10.03 – 18.37	133.2 – 165.0	26.1 – 62.4	14.71 – 24.9
Total sample (N=48)	Mean±SD	10.02±2.82	139.15±14.04	33.24±9.85	16.81±2.43
	Min – Max	5.43 – 18.37	113.5 – 165.0	17.9 – 62.4	13.21 – 24.9

**Legend:** n, N- number of study participants, RGs- rhythmic gymnasts, Mean- average value, SD- standard deviation, Min- minimum, Max- maximum, BMI- body mass index, yrs- years.

Inspecting Table 2, and based on the scale of evaluation of the spine curvatures in the sagittal and frontal plane<sup>1</sup>, it can be said that juvenile RGs have deviations of curvatures in both planes to a large extent. Namely, a wide range of results was observed in the values of curvature in the lumbar part of the spine of juvenile and adolescent RGs (the recommended range goes from 20° to 40°). Such results indicate the prevalence of lordotic posture, which has already been seen in previous studies (Radaković et al., 2016, 2017). When it comes to the status of the thoracic spine in the sagittal plane, a lower prevalence of kyphotic posture was observed, but it should not be ignored. Namely, only three cases of kyphosis (6.3%) and one case of kypholordosis (2.1%) were recorded in the total sample of the study participants, and similar results, in the form of the share of kyphosis and kypholordosis in the sample of RGs, were also recorded in the study of Kums et al. (2007). Also, considering that a wide range of results was observed when it comes

<sup>1</sup> Normal body posture in the sagittal plane of the spinal column, in children, implies a curvature angle of 20° to 45° in the thoracic part and from 20° to 40° in the lumbar part (Milenković et al., 2018). In the frontal plane, lateral deviation of the spinal column up to 10° is considered normal (Newton & Wenger, 2006; Livanelioglu et al., 2016).

to body posture in the sagittal plane, it can be said that a large number of participants deviate from the "lower" limit of normal values of the angles in the thoracic and lumbar parts (below 20° in the thoracic and below 20° in the lumbar) and thus it is concluded that a number of RGs suffer from flat back disorders (*dorsum planum*), which was also seen in the research of Radaković et al. (2016) conducted on a sample of RGs of the same age. When reviewing the results of the participants' body posture in the frontal plane, it can be noted that scoliotic posture is present, but to a much lesser extent compared to postural disorders in the sagittal plane. Namely, in the majority of respondents (40, or 83.33%), the size of the curvature of the spinal column in the frontal plane, both in the thoracic and in the lumbar part, does not exceed 10°, which is a normal body posture in the frontal plane; in one adolescent gymnast, a curve of 11° to the left in the thoracic part was recorded (left thoracic scoliosis); in three, a curve of 13° was recorded, i.e. of 12° in the lumbar part (lumbar scoliosis), and "S" scoliosis was recorded in one juvenile and three adolescent RGs: from 11° to 14° in the thoracic part, and from 12° to 17° in the lumbar part, which was already seen in the study Tanchev et al. (2000), where a higher value of curvature in the lumbar part (lumbar scoliosis) was recorded, and to a lesser extent thoracic scoliosis.

**Table 2.** Descriptive parameters and normality of distribution of spinal curvatures in the sagittal and frontal plane of the study participants

Samples	Variables	KYPH (°)	LORD (°)	TSCOL (°)	LSCOL (°)
Juvenile RGs (n=25)	Mean±SD	21.32±11.22	34.88±9.84	4.28±3.27	7.0±3.67
	Min - Max	-2.0 - 39.0	9.0 - 51.0	0.0 - 12.0	12.0 - 17.0
	K-S (Sig.)	.958	.746	.435	.604
Adolescent RGs (n=23)	Mean±SD	28.26±11.15*	34.57±10.20	5.43±3.70	5.74±3.97
	Min - Max	3.0 - 49.0	10.0 - 50.0	0.0 - 14.0	0.0 - 14.0
	K-S (Sig.)	.943	.708	.456	.524
Total sample (N=48)	Mean±SD	24.65±11.61	34.73±9.91	4.83±3.50	6.40±3.83
	Min - Max	-2.0 - 49.0	9.0 - 51.0	0.0 - 14.0	0.0 - 17.0
	K-S (Sig.)	.994	.440	.189	.443

**Legend:** n, N- number of study participants, RGs- rhythmic gymnasts, Mean- average value, SD- standard deviation, Min- minimum, Max- maximum, K-S- Kolmogorov-Smirnov test, Sig.- significance, KYPH- kyphosis, LORD- lordosis, TSCOL- thoracic scoliosis, LSCOL- lumbar scoliosis.

\* significant at level  $p < 0.05$  (ANOVA)

By comparing the established values of spinal curvatures in the sagittal and frontal plane of RGs of juvenile and adolescent age (Table 2), statistically significant differences ( $p=0.037$ ) were established only in the case of the size of the curvature in the thoracic part of the spinal column in the sagittal plane, "in favor" of adolescent RGs. The differences are not pronounced, but of medium strength (*eta* is .302).

**Table 3.** Prevalence of postural disorders of the spinal column in sagittal and frontal plane in the study participants

Samples	Body posture	Sagittal plane		Frontal plane	
		f	%	f	%
Juvenile RGs (n=25)	Normal	7	28.0	6	24.0
	Deviation	18	72.0	19	76.0
Adolescent RGs (n=23)	Normal	10	43.5	5	21.7
	Deviation	13	56.5	18	78.3
Total sample (N=48)	Normal	17	35.4	11	22.9
	Deviation	31	64.6	37	77.1

**Legend:** n, N- number of study participants, RGs- rhythmic gymnasts, f- frequency.

In the sample of RGs of all ages, a fairly high percentage of postural disorders of the spinal column was recorded in both the sagittal and frontal plane (Table 3). Namely, as many as 64.6% ( $n=31$ ) of the respondents were diagnosed with a deviation from normal body posture in the sagittal plane, and when it comes to deviations in the frontal plane, the prevalence is even higher ( $n=37$ , or 77.1%). The high prevalence of postural disorders in RGs has already been recorded in the previous literature. In the study by Kums et al. (2007), at least one postural disorder in the sagittal and/or frontal plane was recorded in 90.63% of RGs, while in the research of Tsai & Wredmark (1993), as well as Parka et al. (2021), a higher prevalence of disorders in the frontal plane (in 62.96% of respondents) was observed. When the locations of the deviation in the sagittal plane are taken into account, the situation recorded in the RGs is as follows: normal body posture was recorded in 17 subjects (35.41%), flat back in the thoracic part in 11 of them (22.91%), and in the lumbar only in one (2.1%); a flat back in both thoracic and lumbar areas was found in one gymnast (2.1%), and kyphosis in combination with a flat back in the lumbar area was found in three RGs (6.3%); lordotic posture was present in 14 (29.2%) RGs, while kypholordosis was recorded in one girl (2.1%). When it comes to deviations of the spinal column in the frontal plane and their localization, the situation in 48 subjects is as follows: normal body posture was recorded in 11 of them (22.91%); five (10.42%) RGs have thoracic left scoliotic

posture, and only one thoracic right (2.1%); lumbar left scoliotic posture has one gymnast (2.1%), and lumbar right as many as 14 of them (29.2%); total left scoliotic posture was recorded in one subject (2.1%); duplex left-right scoliotic posture was found in 14 of them (29.2%), and duplex right-left in only one (2.1%).

The following reasons can be cited as a basic assumption for the emergence of such a problem in the body posture of RGs: joint laxity, early selection, asymmetric loading of the spine. Therefore, such results (presence of lordosis, scoliosis and lesser presence of kyphosis) are not surprising if we take into account the technical and tactical requirements of this sports discipline, which belongs to a group of asymmetric sports. Namely, in RG there are a lot of single-legged jumps (take-off is realized with the dominant leg), a lot of balances and turns on one (dominant) leg, with or without the help of the hand/s (Purenović-Ivanović et al., 2023), which is a sufficient reason for the deviation of the spinal column in the frontal plane. Also, this is a discipline that abounds in pre-acrobatic elements (cartwheel, walkover forwards and backwards), full body waves (in the sagittal, but also in the frontal plane), for the successful implementation of which, without penalty, a great flexibility of all joints in the body is necessary, especially of the spinal column, mostly in the sagittal plane, which can affect the increase of curvatures, primarily in the lumbar part of the spinal column, but also the decrease of the curve in the thoracic part. It is in this research that kyphotic posture is the least prevalent among participants, although there are studies that show that this postural disorder is most prevalent among girls (Jorgić et al., 2015). To this conclusion also came Radaš & Trošt Bobić (2011) by comparing RGs and non-athletes, when a lower prevalence of kyphotic posture was determined in gymnasts, which suggests that this sports discipline can have a favorable effect to the absence of kyphosis, probably as a consequence of aesthetic requirements, which above all imply constant adoption of an elegant posture during execution of RG individual or group routines. Elegance is determined by many factors, such as an elongated neck, shoulders turned back, pelvis tilted back, a flat stomach, extended knees and slightly open foot position. Since it was previously shown that RGs have stronger trunk extensors than flexors due to specific training loads (Gardocki et al., 2002; Kums et al., 2008), which require the body to adapt and remain in an elegant, upright position, we can assume that it represents a factor that probably has a share in the absence of kyphotic posture in RGs, but affects the increase of the lordotic curvature.

The differences in the prevalence of different types of postural disorders of the spinal column in the sagittal plane were recorded between juvenile and adolescent RGs. First of all, normal body posture in the sagittal plane is more prevalent in adolescent RGs (43.5%) compared to juveniles (28%), which is not in accordance with the results of the study of Rego et al. (2007), where it was proven that RGs through specific sports training have an increased chance of injury or disorders of the spinal column in the sagittal plane after 10–11 years of training.



When it comes to a flat back, primarily in the thoracic region, this type of disorder is more prevalent in the group of younger participants (28% vs. 17.4%), while a flat back in the lumbar region, as well as a flat back and in both thoracic and in the lumbar part, recorded only in one juvenile, i.e. adolescent gymnast, respectively. Using radiography, as a method of determining the postural status of the spinal column on a sample of 100 Bulgarian RGs, aged 10 to 16 years, a group of authors (Tanchev et al., 2000) noticed that almost all of the subjects had flat backs. A possible reason for the difference in the results of our and Bulgarian gymnasts may stem from a different diagnostic method (radiography vs. SpinalMouse®), or from a different training process (Bulgarian vs. Serbian RG school), which can be the subject of future research. When it comes to prevalence of lordotic posture, the difference between juvenile and adolescent RGs is minimal (28% vs. 30.4%); kypholordosis was recorded only in one adolescent gymnast, and the combination of kyphosis with a flat back in the lumbar region in three (12%) juvenile RGs. When analysing prevalence of postural disorders of the spinal column in the frontal plane, by localization, in RGs of juvenile and adolescent age, the first noticeable is the higher prevalence of normal body posture in the younger subsample of gymnasts (24% vs. 21.7%), which can be attributed to shorter sports experience and less training load. When it comes to lumbar right, as well as duplex left-right scoliotic posture, the situation is identical – a higher percentage of both disorders was recorded in juvenile RGs (32% vs. 26.1%). Scoliotic posture in the thoracic part, left and right, was recorded only in adolescent gymnast (21.7% and 4.3%, respectively). Only in the subsample of juvenile gymnasts, the following postural disorders in the frontal plane were recorded: lumbar left, total left, and duplex right-left scoliotic posture. From this it can be concluded that scoliotic posture is a frequent postural problem in RGs, which is not surprising because RG is a sport that requires great flexibility of the hip joint in various conditions of maintaining balance, both static and dynamic, most often in the one-legged standing position. Therefore, during 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. In other words, RGs are forced to break their posture by practicing certain stances, positions and movements in order to be able to perform demanding elements smoothly, and this can potentially lead to scoliosis due to asymmetric loading of the spine. Although, it is clearly seen that between juvenile and adolescent rhythmic gymnasts, there are differences in the prevalence of postural disorders of the spinal column, primarily in the sagittal, but slightly in the frontal plane, the results of the Chi-square test show that these differences are not statistically significant [sagittal plane:  $\chi^2(1,48)=1.255, p=0.263$ ; frontal plane:  $\chi^2(1,48)=0.035, p=0.852$ ], which is in line with existing literature (Parka et al., 2021).

It must be noted that most studies (Tanchev et al., 2000; Kums et al., 2007; Radaković et al., 2016) used different methods for determining postural status,

and obtained similar results regarding the prevalence of postural disorders in the sagittal and frontal plane. Studies that used the same diagnostic methods, e.g. radiography (Tanchev et al., 2000; Parka et al., 2021), reached similar results regarding the prevalence of scoliosis in RGs (on average 60.67% of respondents), but also research that used different methods, such as Napoleon Wolansky's method (Radaković et al., 2017), where scoliosis was found in 48% of the subjects, or the Sagittal Arrows Test in the study of Galán & Rosa (2019), where a similar percentage (44.5%) was observed, which indicates that there is no inconsistency of results despite the application of different diagnostic methods. It can be stated that the results in a vast number of studies, which were conducted on the same sample, are similar or the same. In this regard, such results could be attributed to the nature of this specific sport, ie. RG, where it has been shown that flexors and extensors of the spinal column are quite balanced (Parka et al., 2021), but the lateral flexors show a noticeable imbalance, which leads to an increase in the possibility of scoliotic posture in RGs.

## CONCLUSION

The obtained results (presence of lordosis, scoliosis and lesser presence of kyphosis) are not surprising if we take into account the technical and tactical requirements of this sports discipline, which abounds in pre-acrobatic elements, for the successful implementation of which a great joint flexibility is necessary, especially of the spinal column, mostly in the sagittal plane, which can affect the increase of curvatures, primarily in the lumbar part, but also the decrease of the curve in the thoracic part. Namely, this research has shown that this sports discipline can have a favorable effect on the absence of kyphosis, probably as a result of aesthetic requirements, which first of all imply the constant adoption of an elegant stance during the execution of RG routines. Unlike kyphotic posture, scoliotic posture is a more frequent postural problem in RGs, which is not surprising, because it is a sport that requires great flexibility of the hip joint in various conditions of maintaining balance, both static and dynamic, most often while standing on one leg. Therefore, during training, most gymnasts perform various positions and movements that involve excessive use of certain muscle groups and include unilateral flexion in the hip joint, which causes functional muscle imbalance. In other words, RGs are forced to constantly break their posture in order to be able to perform demanding elements smoothly, and this can potentially lead to scoliosis due to asymmetric loading of the spine. In order to reduce and eradicate this trend, it is recommended that rhythmic gymnastics coaches insist that their competitors engage the muscle groups of both the left and right sides of the body equally (to perform balances, rotations and walkovers backward and forward on both the right and left leg, as well as take-offs prior

jumps). Even better results in solving this problem would be achieved by changes in the RG Code of Points by introducing the requirement that at least 50% of all types of body difficulties must be performed with the non-dominant leg (take-off prior jumps), or on the non-dominant leg (balances and turns).

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