THE LEVEL OF DORSIFLEXION IN YOUNG GYMNASTS COMPARED TO YOUNG ATHLETES - PILOT STUDY

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Abstract

Gymnastic training develops strength, flexibility, concentration, balance, precision, and speed. The purpose of the study is to determine if gymnastic preparation leads to an increase in weight-bearing ankle dorsiflexion range of motion in a closed kinematic chain in young artistic gymnasts compared to a different type of sport. The weight-bearing lunge was chosen to measure the dorsiflexion range of motion in the ankle joint in the closed kinematic chain. The first group consists of members of the Slovak national youth team in artistic gymnastics (n-26). The second group consists of members of the Slovak national team in rhythmic gymnastics (n-13). The control group consists of young athletes (n-22). The mean dorsiflexion range of motion in artistic gymnasts was 47.32 ° in the right ankle joint and 44.75 ° in the left ankle joint. The mean dorsiflexion range of motion in rhythmic gymnasts was 44.32 ° in the right ankle joint and 43.41 ° in the left ankle joint. The mean dorsiflexion range of motion in young athletes was 44.27 ° in the right ankle joint and 42.32 ° in the left ankle joint. Results indicate a statistically significant difference in favor of artistic gymnasts compared to rhythmic gymnasts at the right ankle joint (p-0.04). In the left ankle, the two groups did not differ significantly from each other (p-0.38). There was no significant difference between artistic gymnasts and athletes in the right ankle joint (p-0.09) and the left ankle joint (p-0.19). There was no significant difference between rhythmic gymnasts and athletes at the right ankle joint (p-0.38) and the left ankle joint (p-0.24). A greater dorsiflexion range of motion in a closed kinematic chain in the ankle joint was detected in young gymnasts compared to rhythmic gymnasts. There was no significant difference between artistic gymnasts and athletes.

Keywords: *weight-bearing lunge test, range of motion, artistic, rhythmic gymnasts, athletics.*

INTRODUCTION

Gymnastics requires a high level of ability of motor control and a combination of several attributes to achieve optimal performance (Marcolin et al., 2019; Nassib et al., 2020). Gymnastics is a complex sport. Gymnastics can be divided into sports, modern, acrobatic, rhythmic, and aerobic gymnastics. Other gymnastic disciplines include tumbling and trampoline jumping. In artistic gymnastics, men have six apparatuses - floor exercise, pommel horse, rings, vault, parallel bars, and horizontal bar - on which they showcase their skills. Women compete on four apparatuses - vault, uneven bars, balance beam, and floor exercise. Modern rhythmic gymnastics is one of the few purely women's sports. Its main characteristic is the inclusion of equipment in exercises: skipping rope, hoop, ball, cones, and ribbon.

Gymnastics is a type of sport that requires a high level of anaerobic activity to achieve optimal results. Additionally, gymnastics enhances the development of abilities such as explosive strength, balance, coordination, and agility. The gymnast controls numerous basic elements to adapt to a higher load. Gymnastics also requires a high level of neuromuscular control (Kochanowicz et al., 2018). Repetition of difficult elements in training leads to skeletal adaptations (Knorr, 2014). The human body is adaptable due to its ability to react to repetitive loading. The human locomotor system is especially sensitive to adaptive changes during the adolescence period. Adaptation of range of motions in various joints is one of the adaptive factors for young gymnasts. Both decreasing or increasing the range of motion increases the risk of injury to gymnasts. Prevention of injuries in gymnastics is a great challenge (Kerr, 1990). In gymnastics, acute and chronic injuries can occur (Desai et al., 2019; Kolar et al., 2013). The most common cause of chronic injuries in gymnastics is overloading or inadequate treatment of acute injuries (Bradshaw & Hume, 2012; De Carli et al., 2012). The biomechanics of gymnastic exercises leads to the unique involvement of the body in different positions. These positions often require an excessive range of motion in various joints. It can lead to a higher incidence of hypermobility in gymnasts and predisposition to injury. Higher incidence of generalized joint hypermobility may result in musculoskeletal injuries in many sports activities (Schmidt et al., 2017). In addition to generalized hypermobility, localized hypermobility increases the risk of injury (Antonio & Magalhaes, 2018). In general, there is a higher incidence of hypermobility in gymnastics compared to other sports. One of the most common injuries in this sport is ankle joint injury (Edouard et al., 2018; Hart et al., 2018).

There are several testing possibilities to measure the range of motion of the ankle joint. Measurement using a weight-bearing lunge test in a closed kinematic chain is potentially one of them. This pilot study aims to determine the weight bearing ankle dorsiflexion range of motion in a closed kinematic chain in young artistic gymnasts compared to athletes engaging in different sports, and to determine whether gymnastic training causes hypermobility in the ankle joint.

METHODS

Three groups of athletes participated in the study – young artistic gymnasts, rhythmic gymnasts, and young athletes. Young athletes included in the study train for a minimum of two years in a certain sport and only in one discipline. Athletes who train in more than one sport discipline and athletes with acute lower limb injury or infectious disease were not included in the study. Gymnasts were tested in January 2021, during a gymnastic team camp in X-Bionic Sphere in Šamorín. The athlete testing took place in Banská Bystrica. Testing was conducted before training so that training did not affect the range of motion in the ankle joint. The informed consent was signed by the parents.

The first group consisted of 26 members of the Slovak national youth team in artistic gymnastics. Of these, 13 gymnasts were female and 13 gymnasts were male. The mean age was 14.28 years (±2.90). The mean weight was 47kg (±2.90). The mean height was 156.65 cm (±10.12). The mean training time was 9.34 years (±3.16). The median training time was 9 years.

The second group consisted of 13 female members of the Slovak national team in rhythmic gymnastics. The mean age was 14.84 years (±1.20). The mean weight was 48kg (±7.4). The mean height 162 cm (±4.4). The mean training time was 11 years (±1.8). The median training time was 11 years.

The third group consisted of 22 members of an athletic training group for children. Of these, 10 athletes were female and 12 athletes were male. The mean age was 13.54 years (±1.4). The mean weight was 47,14kg (±7.79). The mean height was 160, 7 cm (±9.55). The mean training time was 4.36 years (±1.68). The median training time was 4.5 years.

Artistic gymnastics training

Sports preparation in artistic gymnastics consists of physical activity focused on the development of physical abilities and aesthetic awareness. In competition, athletes perform their routines with standardized apparatuses. Evaluation of every routine reflects its difficulty and execution value according to the current Code of Points. Talent identification and selection in gymnastics occurs in children aged 4 to 5 years. At the age of 11 to 14 years, athletes already train 5 times a week; the mean time per training unit is 180 min. Training focuses mainly on mastering flawless techniques for difficult elements. It must consist of a comprehensive development of physical abilities and increasing the difficulty of routines in every discipline. The best gymnasts participate in international competitions. Typically, they participate in 6 to 10 competitions a year.

Rhythmic gymnastics training

Rhythmic gymnastics is coordination – aesthetic sport. It combines ballet, dance, and acrobatics with expressive movement and manipulation of hand apparatuses. Performance in rhythmic gymnastics consists of mostly noncyclic movements demanding a high level of neuromuscular coordination. Gymnasts perform a variety of body movements, often using a maximum range of motion with music and according to the current Code of Points. Training consists of developing a technique of floor (freehand) exercises such as leaps, balances, pivots, and flexibility movements along with techniques of manipulating the hand apparatuses such as tossing, catching, and rolling. Rhythmic gymnasts begin with systematic training at a very young age, achieving maximum performance before 20. At preschool age, training focuses mainly on the comprehensive development of all physical abilities. For young gymnasts, it is necessary to gain control over coordination in connecting various body movements and basic skills. Young gymnasts train five times a week, 3–5 hours a day, focusing mainly on joint flexibility, especially the hip joint and spine.

Young athletes training

Many children at the age of 13 already have 4–8 years of systematic training behind them. The mean time of a training unit is 60 min, twice a week. Training consists of athletic exercises, gymnastic exercises, conditioning, and sports games (Čillík & Willweber, 2018). Children participate in athletic competitions several times a year. Preparation focuses on building a foundation for simple athletic disciplines – sprints, middle-distance running, relay running, long jump, high jump, and ball throw. Training is universal, varied, and conducted in a playful way. At the age of 12 to 13 s, athletes train 3 times a week, 60 to 90 minutes per training unit. Training focuses mainly on achieving the correct technique in basic athletic disciplines. Regional competitions take place 7 to 8 times a year. Training is still very comprehensive at both levels an focuses on the development of physical abilities and athletic disciplines.

Weight-bearing lunge test.

The weight-bearing lunge test focuses on measuring the dorsiflexion range of motion in the ankle joint in the closed kinematic chain. The test is conducted in a lunge position using a goniometer. The tested athlete performs lunge position with heel and hallux aligned. An attempt is not valid if knee valgus-varus occurs or if the heel lifts off the floor. The heel is in contact with the floor during the whole movement. The physician ensures that the ankle joint reaches maximum dorsiflexion in the lunge position. The other lower limb stays on the floor. The physician measures the angle of dorsiflexion in the ankle joint. The mobile application was used for the testing (Banwell et al., 2019; Williams et al., 2013).

All three groups were tested before training without warming up.

Results were collected in an Excel spreadsheet and subsequently subjected to statistical analysis using software SAS® Enterprise Guide® (SAS Institute Inc., USA). Non-parametric tests were used. The difference in the mean values for the right ankle joint and the left ankle joint between three groups has been evaluated with Kruskal-Wallis one-way analysis of variance. To assess the difference in the mean values for the right ankle joint and the left ankle joint between two groups, Wilcoxon scores have been calculated using Wilcoxon Rank Sum Test. Pearson's correlation coefficient was used to test the correlation.

RESULTS

Table 1

Mean range of motion dorsiflexion (ROM) in artistic gymnasts, rhythmic gymnasts and athletes.

Average ROM (°) Group		Right	Left
Artistic gymnasts	Min	33.00	30.50
	Mean	47.32	44.75
	Max	63.00	65.00
	Range	30.00	34.50
	QRange	8.00	10.00
Rhythmic gymnasts	Min	36.00	35.20
	Mean	44.32	43.41
	Max	51.00	49.50
	Range	15.00	14.30
	QRange	6.00	3.30
Athletes	Min	29.00	29.00
	Mean	44.27	42.32
	Max	56.00	54.00
	Range	27.00	25.00
	QRange	11.00	9.00

Table 2

Mean range of motion dorsiflexion (ROM) in male and female.

Average ROM (°) Group	Sex		Right	Left
Artistic gymnasts	Female	Min	33.00	32.00
		Mean	47.88	44.45
		Max	57.00	62.50
		Range	24.00	30.50
		QRange	6.50	6.90
	Male	Min	36.00	30.50
		Mean	46.76	45.05
		Max	63.00	65.00
		Range	27.00	34.50
		QRange	9.20	11.00
Rhythmic gymnasts	Female	Min	36.00	35.20
		Mean	44.32	43.41
		Max	51.00	49.50
		Range	15.00	14.30
		QRange	6.00	3.30
Athletes	Female	Min	29.00	29.00
		Mean	43.30	40.80
		Max	56.00	54.00
		Range	27.00	25.00
		QRange	14.00	7.00
	Male	Min	36.00	36.00
		Mean	45.08	43.58
		Max	50.00	52.00
		Range	14.00	16.00
		QRange	10.00	8.50

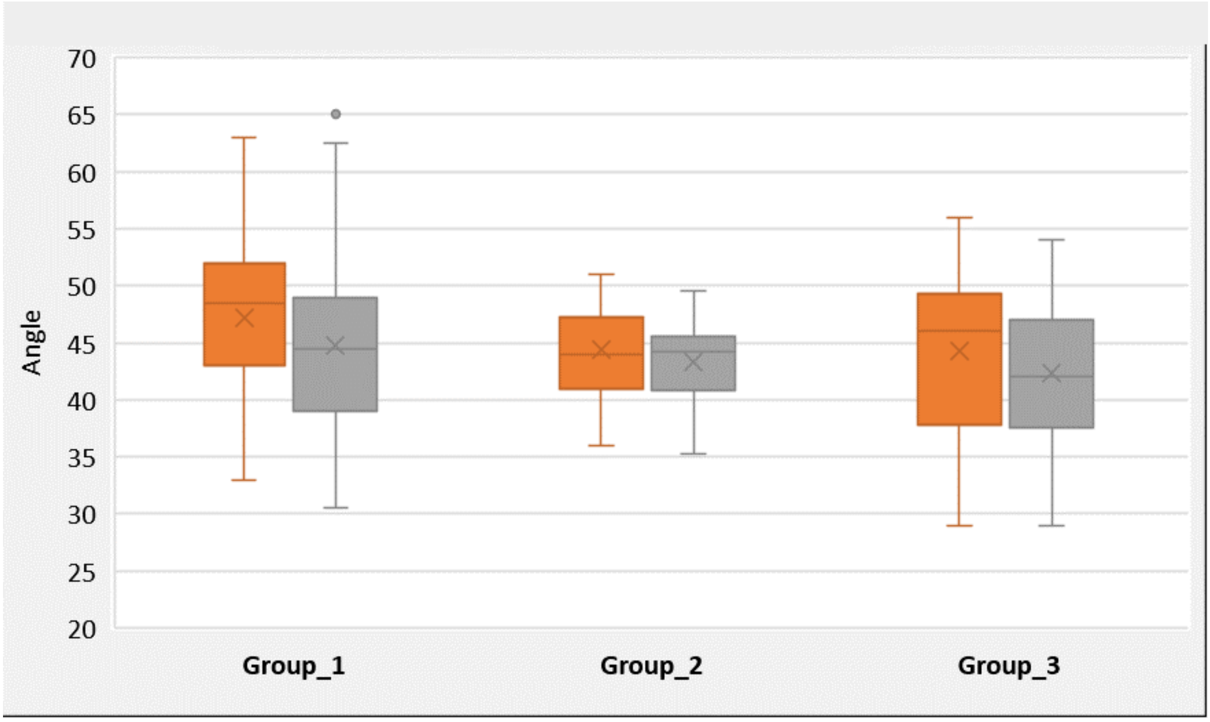

Figure 1. Comparison between artistic gymnasts, rhythmic gymnasts and athletes.

Table 3
Statistical difference between groups of artistic gymnasts (AG), rhythmic gymnasts (RG), and athletes (AT).

	All		Female		Male	
GROUPS	Right	Left	Right	Left	Right	Left
AG - RG	0.0417	0.3883	0.0231	0.4421	x	x
AG - AT	0.0904	0.1865	0.0907	0.1755	0.3708	0.3515
RG - AT	0.3848	0.2371	0.4532	0.0886	x	x

The mean dorsiflexion range of motion in artistic gymnasts was 47.32 ° in the right ankle joint and 44.75 ° in the left ankle joint. The mean dorsiflexion range of motion in rhythmic gymnasts was 44.32° in the right ankle joint and 43.41° in the left ankle joint. The mean dorsiflexion range of motion in young athletes was 44.27° in the right ankle joint and 42.32° in the left ankle joint. The results can be seen in Table. 1

The mean dorsiflexion range of motion in artistic gymnasts was 47.88 ° in the right ankle joint and 44.45 ° in the left ankle joint. The mean dorsiflexion range of motion in male artistic gymnasts was 46.76 ° in the right ankle joint and 45.05 ° in the left ankle joint. The mean dorsiflexion range of motion in rhythmic gymnasts was 44.32° in the right ankle joint and 43.41° in the left ankle joint. The mean range of motion of dorsiflexion in young female athletes was 43.30 ° in the right ankle joint and 40.8 ° in the left ankle joint. The mean dorsiflexion range of motion in young male athletes was 45.08 ° in the right ankle joint and 43.58 ° in the left ankle joint. The results can be seen in Table. 2.

Furthermore, we compared the statistical significance at α-0.05 significance level -0.05.

There was a significant difference in favor of artistic gymnasts compared to rhythmic gymnasts in the right ankle joint (p <0.04). In the left ankle joint, no significant differences were found (p-0.38). There were no statistically significant differences between artistic gymnasts and athletes in the right ankle joint (p-0.09) and the left ankle joint (p-0.19). No significant differences were found between rhythmic gymnasts and athletes in the right ankle joint (p-0.38) or the left ankle joint (p-0.24). A significant difference was detected in favor of female artistic gymnasts compared to rhythmic gymnasts (p-0.02) in the right ankle joint and no significant difference (p-0.44) in the left ankle joint. There were no significant differences between artistic gymnasts and athletes in the right ankle joint (p-0.09) and the left ankle joint (p-0.18). A significant difference was not detected between male artistic gymnasts and male athletes in the right ankle joint (p-0.37) or the left ankle joint (p-0.35). There was no significant difference between rhythmic gymnasts and female athletes in the right ankle joint (p-0.45) and the left ankle joint (p-0.08). The results can be seen in Table 2

Dorsiflexion in artistic gymnasts did not correlate with age (r-0.13-0.19), weight (r- 0.28-0,29), and sport age (r- 0.21-0.31). The range of motion of dorsiflexion in rhythmic gymnasts did not correlate with age (r-0.36), weight (r- 0.04-0.12), and sport age (r-0.22-0.30). In the young athlete’s dorsiflexion range of motion did not correlate with age RL (r-0.20), weight RL (r-0.13-0,15), and sport age (r-0.12-0.20)

DISCUSSION

Gymnastic training develops strength, flexibility, concentration, balance, precision of movement, and speed in young gymnasts. Young gymnasts dedicate a considerable amount of time to training (Zetaruk, 2000). Physical loading during training time stimulates changes in the musculoskeletal system. These changes have positive or negative effects. Maintaining a balance between flexibility and strength, training modification, and correct training periodization reduces the risk of injuries in the case of excessive training.

The highest mean range of motion for dorsiflexion was confirmed in the group of young gymnasts. These findings support the assumption that gymnastic training leads to adaptation of the musculoskeletal system including the dorsiflexion range of motion in the ankle joint. Despite a higher mean of dorsiflexion range of motion in the ankle joint, it still did not lead to hypermobility in young gymnasts. The appearance of dorsiflexion hypermobility in all groups was influenced by individual flexibility in the various joints rather than by the type of sport itself. A significant difference was found between female artistic gymnasts and rhythmic gymnasts. We assumed a greater dorsiflexion range of motion in the ankle joint in rhythmic gymnasts. This assumption was not confirmed; rhythmic gymnasts had a significantly lower dorsiflexion range of motion in the ankle joint. A possible explanation for this finding is that rhythmic gymnasts perform most of the movement in plantar flexion rather than in dorsiflexion in the ankle joint. The musculoskeletal system of rhythmic gymnasts lacks an adaptive stimulus to increase the range of motion of dorsiflexion. The mean range of motion of dorsiflexion in the ankle joint in artistic gymnasts was greater than in athletes. However, the difference was not statistically significant. Gymnastic training requires more flexibility training than athletic training. On the other hand, athletic training focuses on numerous activities that involve the ankle joint in various directions. It can lead to natural adaptation of a range of motion in the ankle joint. In the training of young athletes, adequate range of motion in the ankle joint is essential for sports performance, especially in sprints and jumps.

In a previous study (Líška et al., 2021), we focused on comparing the range of motion of judo and football players. The mean dorsiflexion range for judoists was 43.15-43.90° and for football players 41.02-42.09°. Compared to gymnasts in our study, the dorsiflexion was lower, which may indicate that gymnastic training involves more complex training for ankle joint than judo and soccer.

Systematic sports training in different disciplines leads to functional and structural adaptation of the human organism. In a systematic review, Jürimäe (Jürimäe et al., 2018) monitored the influence of gymnastic training on one group compared to another group without gymnastic training. The group of gymnasts had better bone density, lower body weight, delayed pubertal development, and lower levels of some hormones. Bukva et al. (2019) examined the association between generalized hypermobility in gymnasts. To examine the gymnasts, Beighton score was used. The sample consisted of 24 rhythmic gymnasts. The most common injury was lower back pain, followed by knee, shoulder, hip, and ankle injuries. The number of training years was correlated with the prevalence and incidence of injuries ($P<0.001$). The number of training hours per week was not correlated with the incidence of injuries ($P>0.05$). Young gymnasts are at an increased risk of injury due to overload. An overload injury occurs when there is an inadequate ratio between the training load and regeneration. In young gymnasts, inadequate body adaptation to the training load and inadequate range of motion at the ankle joint increase the risk of injury. Sweeney et al. (Sweeney et al., 2019) examined the relationship between flexibility and lower back pain in rhythmic gymnasts: 30 of 67 gymnasts experienced lower back pain in 5 years. Gymnasts who experienced lower back pain were those with higher age (11.7 vs 13.7, $P = 0.005$), weight (37.5 vs 43.4 kg, $P = 0.049$) and training time (19.1 vs 22.4 h / week, $P = 0.017$).

Gymnasts use various training methods to increase their range of motion. Dallas et al. (Dallas et al., 2014) examined the acute effect on flexibility in gymnasts using static stretching, proprioceptive, neuromuscular facilitation, and stretching on a vibrating platform. The most significant changes in the range of motion were found in the group using proprioceptive neuromuscular facilitation.

In our study, the weight-bearing lunge test was used to measure dorsiflexion in the ankle joint in the closed kinematic chain as a pilot test in gymnastics. This test was used in other sports, for example, in football. The range of motion of dorsiflexion in the ankle joint changes during the season depending on the level of physical activity. Moreno-Peréz (2020) examined this issue. The sample consisted of 45 football players tested before and after the match to determine the acute effect of physical activity. The long-term effect was tested before, during and after the competitive season. The dorsiflexion range of motion in the ankle joint in the closed kinematic chain was at the highest level. The preseason values were higher than the midseason values (8.1% dominant lower limb and 9.6% non-dominant lower limb). Post-season tests showed a significant decrease in dorsiflexion range of motion in the ankle joint (13.8% dominant lower limb, 12.5% non-dominant lower limb). A decrease in the dorsiflexion range of motion occurred in 30% of football players. An increase in dorsiflexion range of motion after the match indicates the immediate effect of physical activity (5.8% dominant lower limb). This increase in the dorsiflexion range of motion decreased during the next 48 hours. According to Moreno-Peréz, the decrease in the dorsiflexion range of motion in the ankle joint is related to a higher risk of injury during the mid-season and post-season period. Backman et al. (2011) also examined the relationship between injuries and the limited range of motion of dorsiflexion in the ankle joint. The sample consisted of 75 junior basketball players monitored during one season. Twelve of them experienced patellar tendinopathy during the season. They also had lower dorsiflexion range of motion in the ankle joint (P=0.038) in the dominant lower limb and in the nondominant lower limb (P = 0.024). Another data shows that players with dorsiflexion range of motion in the ankle joint less than 36.5° were at 18.5% to 29.4% higher risk of suffering patellar tendinopathy in one year compared to players with dorsiflexion range of motion in the ankle joint greater than 36.5° (1.8% - 2.1%). Macrum et al. (2012) examined the effect of limited dorsiflexion range of motion in ankle joints in a squat. The sample consisted of 30 participants who performed no-restriction squat-simulating motion restriction in the ankle joint. Limiting the range of motion in the ankle joint led to an increase in the knee valgus. Simultaneously, simulating motion restriction in the ankle joint is related to a lower activation of the m.quadriceps femoris and a higher activation of the m.soleus.

The optimal range of motion in the ankle joint in the closed kinematic chain in gymnasts is an important issue to be determined in future studies by examining the relationship between gymnastic training and the range of motion in the ankle joint. Determining the optimal range of motion of dorsiflexion enables setting the optimal reference values and advances the gymnastics training process. Training time was the limiting factor in influencing the validity of the tests in both groups of gymnasts in comparison to athletes. The mean training time of young athletes has been lower compared to gymnasts of the same age. However, the number of years of training did not correlate with the overall effect on the range of motion of dorsiflexion in the ankle joints in any group. To confirm the validity of this statement, it is important to test the potential relationship between different groups of professional gymnasts and athletes. Another limitation of our study was the relatively small sample.

CONCLUSIONS

A greater dorsiflexion range of motion in a closed kinematic chain in the ankle joint was detected in young gymnasts compared to rhythmic gymnasts. There was no significant difference between artistic gymnasts and athletes.

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