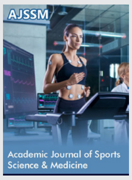

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Research Article

Effects Of Core Stabilization Exercise Program on Trunk Muscle Endurance, Balance, And Athletic Performance in Artistic Gymnast Children

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Abstract

Purpose: Core muscle training is predicted to provide a basis for improving trunk stability and performance. Especially, given the difficult movement patterns in gymnastics, the muscles in the lumbopelvic region are much more important. However, the effects of core stabilization training on gymnast children are not well known. The aim of this article is investigating the effects of core stabilization exercise program on trunk muscle endurance, balance, and athletic performance in artistic gymnast children.

Methods: 51 children participated in this quasi-experimental study. The individuals are divided into three groups. In the first group, the individuals performed core stabilization exercises in addition to their gymnastic training. The second group only did routine training. The third group consisted of sedentary children. McGill core endurance tests, Flamingo and Y balance tests and vertical jump tests evaluated before and after the 8-week intervention.

Results: The between-groups comparisons showed that participants in the group of gymnastics and core stabilization exercises had significant differences on the measurements of flexor, extensor, left lateral flexor trunk endurance, and anterior, posteromedial and composite reach distances, and vertical jump height (p's<0.05). The results of within-group comparison showed that measurements of trunk muscle endurance, static and dynamic balances, and explosive strengths demonstrated significant differences before and after intervention (p's <0.05).

Conclusion: Adding core stabilization exercises in gymnastic training is effective in increasing muscle endurance, improving balance and performance.

Keywords: Exercise Training; Children; Gymnastics; Athletic Performance

Introduction

Strong core muscles dynamically stabilize the pelvis during functional movements and provide maximum resistance to fatigue. By this means, movements become more efficient, and the continuity of appropriate posture and techniques specific to the sport is provided. Core muscle training is predicted to provide a basis for greater torque generation in the upper and lower extremities by improving trunk stability and performance. In recent years, it was realized that core stabilization exercises are important for increasing the core strength and endurance of athletes, and it took its place in training programmes to improve performance [1]. Given the difficult movement patterns in gymnastics, the muscles in the lumbopelvic region are much more important than the other extremity muscles and are the main muscles that need to be developed [2]. Core stabilization training is needed due to the presence of spin and rotation components in many movements in gymnastics. However, the effects of core stabilization training in gymnastics are not well known [3].

When creating specific core stabilization programmes for athletes, an exercise programme including all isometric, concentric, and eccentric contractions should be developed to activate both local and global core muscles [4]. However, Prieske et al. stated that there is a lack of core stabilization strengthening programmes, in which all treatment characteristics (frequency, number of sets/repetitions) are given in detail [5]. This study aims to investigate the effects of the core stabilization exercise training programme on trunk muscle endurance, balance, and athletic performance in artistic gymnast children.

Material and Methods

Participants

The sample size of the study was calculated using the G*Power (version 3.1.9.2) computer program. The sample size of the study was calculated as 39, with the assumption that the number of groups would be 3, the number of dependent variables would be 6, $\alpha=0.05$, $\beta=0.20$, and $f=0.40$. The sample size was increased by 25% considering that some of the participants who would participate in the eight-week exercise programme could leave the study, and the study was conducted on a total of 51 participants, 17 participants in each group.

Participants aged between 7 and 9 years who attended artistic gymnastics training were divided into two groups by simple random sampling. In the first group, core stabilization exercise training was added to their regular training programme. The second group attended regular gymnastics training. The third group (control) consisted of sedentary children of the same age and gender. The participants in the control group were recommended to continue their normal daily life for 8 weeks. Female children who were regularly attending in an artistic gymnastics training programme in the last 3 months included to the study. Participants who have a lower extremity or spinal pathology, a history of surgical procedure, neurological and vestibular impairments, vision problems other than refractive error were excluded from the study.

Procedure

Core Stabilization Exercises

Core stabilization exercises were performed 3 days a week for 8 weeks and each session was 45-60 minutes. The exercise protocol was implemented in a way to show progress every 2 weeks. Each session consisted of 10 minutes of warm-up, 30-45 minutes of core stabilization exercises, and 5 minutes of cool-down periods. During the warm-up period, after a 5-minute jogging, dynamic stretching was performed for 5 minutes to include all major muscle groups. During the cool-down period, the stretches performed during the warming period were repeated. All exercises were performed in combination with respiration [Table 1].

Table 1: Core Stabilization Exercise Program.

Exercises	Set / Repetition / Duration			
	1-2 weeks	3-4 weeks	5-6 weeks	7-8 weeks
Superman	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 20 reps
Swimmer	2 sets / 15 sec	2 sets / 20 sec	3 sets / 25 sec	3 sets / 30 sec
Supine Bridge	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 20 reps
Donkey Kick	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 20 reps
Prone Leg Extension	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 20 reps
Prone Plank	2 sets / 15 sec	2 sets / 20 sec	3 sets / 25 sec	3 sets / 30 sec
Sit-Up	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 20 reps
Flutter Kick	2 sets / 15 sec	2 sets / 20 sec	3 sets / 25 sec	3 sets / 30 sec
Dead Bug	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 15 reps
Side Plank	2 sets / 15 sec	2 sets / 20 sec	3 sets / 25 sec	3 sets / 30 sec
Cross over Crunch	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 20 reps
Russian Twist	2 sets / 10 reps	2 sets / 15 reps	3 sets / 15 reps	3 sets / 20 reps

Artistic Gymnastics Training

Artistic gymnastics training was conducted by a professional gymnastics' instructor of the TRNC Gymnastics Federation. The programme was administered 2 days a week and 1 hour per day. This training included exercises to increase strength and flexibility for large muscle groups of children, as well as gymnastics specific movement and choreography teachings such as bridge, glider, eagle, split, circle, flick flack, handstand, etc. to train professional gymnasts.

Measures

After the socio-demographic and sport-related characteristics of the participants were recorded, the following tests were applied.

All evaluations were performed by the same physiotherapist. In order to eliminate the fatigue, evaluations were made in random order.

McGill's Core Endurance Tests

McGill's Core Endurance tests which are the primary outcome measure of the study (the trunk anterior flexor test, the right and left lateral bridge tests, and trunk posterior extensor test) were used to examine participants' core endurance [6].

Trunk Flexion Test: The test was performed to evaluate the static endurance of abdominal muscles. Participants were positioned with their hands crossed in front of them, trunks inclined at 60 degrees, both hips and knees flexed to 90 degrees, and ankles fixed. The test was shown to the children by the researcher in advance and they were pre-tested. With the start command, the back support was removed and the time until the position was broken was recorded with the stopwatch.

Trunk Extensor Test (Biering-Sorensen Test): Trunk Extensor test was used to evaluate the static endurance of the back extensors. The subjects were positioned in the prone position with their trunk hanging from the bed starting from the anterior superior iliac spine, and their legs were fixed. The subjects with hands crossed in the front were asked to keep their bodies parallel to the ground against gravity. The test was started with the start command, and the time until the subject can no longer maintain the position was recorded with a stopwatch.

Lateral Bridge Test: The test was performed to evaluate the static endurance of the trunk lateral muscles. The participants were positioned in the side-lying position with the lower arm flexed from the elbow and the other hand in the waist position. With the start command, participants raised their hips and knees to form a bridge position. Then the time until the subject can no longer maintain the position was recorded with a stopwatch.

Flamingo Balance Test: The flamingo balance test was performed to evaluate the static balance. Participants tried to maintain their balance by standing on the wooden beam with their dominant foot bare. After the child stabilized on the 50 cm long, 4 cm high, and 3 cm wide wooden beam, the stopwatch was started. The stopwatch was stopped as soon as the balance deteriorated and did not restart until balance was restored. The motion continued for one minute. At the end of one minute, the number of times the child attempted to restore balance was recorded and this number was used as the test score. In the event of more than 15 balance losses within the first 30 seconds, the test was terminated and score of zero was given [7].

Y Balance Test: In order to evaluate the dynamic balance, the participants standing on the dominant foot on the Y balance test device extended their free foot as far as possible to the anterior, posteromedial, and posterolateral directions of the stance limb. The test was discarded and repeated if the extremity touched the ground while reaching the target points, if the individual slipped from the midpoint where their evaluated foot was fixed, and if the participants lost before completing reaching all three target points. The test was performed 3 times for the dominant side with 120-sec rest intervals. As a result of three trials, the maximum value reached in the test was recorded in centimeters. Composite reach distance (CRD) was calculated as follows; CRD= [(max anterior + max posteromedial + max posterolateral) / (3 × Lower Extremity Length)] × 100 [8].

Vertical Jump Test: The vertical jump test was used to assess the explosive strength of the lower extremity. The subjects were asked to stand in an upright position before starting the test, and jump immediately after the hip and trunk flexion, accelerating with arms, to reach as high as possible. The distance between the standing reach height and the jump height was measured and recorded in centimeters. The best of three attempts was recorded [9].

Statistical Methods

Data obtained from the study were analyzed using IBM SPSS Statistics V.20.0.0 program. The variables used in the study were indicated by number, percentage (%), and mean ± standard deviation (x ± SD). The Shapiro-Wilk test was used to determine whether the data fit the normal distribution. Since the p values obtained by the Shapiro-Wilk test were found to be higher than 0.05, it was decided that the data were distributed normally, and parametric statistical tests were used for statistical analysis. The independent group t-test was used to test the difference between two independent groups and one-way ANOVA was used to test the difference between more than two groups. In the post-study comparisons, for the variables with differences between the first measurements, the differences were analyzed by checking the General Linear Model. For intra-group comparisons, the t-test was used for dependent samples. The statistical significance level was set at $p<0.05$. In addition to the p-value, 95% confidence interval (CI) levels were also taken into consideration. In cases where the confidence intervals overlap or the 95% CI contains the number 0 in the difference between the two means, it was concluded that there was no significant difference between the means even if the p-value was less than 0.05. In order to determine the efficacy of the treatment, the clinical effect size was calculated using Rosenthal's formula: $r_{equivalent} = \sqrt{\frac{t^2}{t^2 + (N-2)}}$

If $r \geq 0.5$, it was interpreted as large effect, $r = 0.3$ as medium effect and $r \leq 0.1$ as small effect [10].

Ethics

This quasi-experimental comparative study was approved by the Eastern Mediterranean University Research and Publication Ethics Committee (ETK00-2018-0156). Before starting the study, the families and children were informed about the purpose, and content of the exercise programme, and families were asked to sign the informed consent form.

Results

Participants in all three groups were statistically similar in terms of age, duration of education, and dominant side ($p>0.05$).

On the other hand, significant differences were found between the groups in height, body weight, body mass index, and lower limb length (p<0.05) [Table 2]. The average duration of gymnastics training in the first group was 12.9 ± 6.8 months. This value was 9.7 ± 7.8 months for the second group. The two groups were statistically similar in terms of this variable (p>0.05). The participants in the first and second groups were trained twice a week. The average training time was 60 minutes, which was statistically similar (p>0.05). The static trunk muscle endurance and explosive strengths of the participants in the first group were found to be statistically different before the study (p<0.05). However, there was no significant difference between the groups in terms of static and dynamic balance values (p>0.05) [Table 3]. At the end of the 8 weeks, trunk muscle endurance was found to be statistically different between the groups except for the right lateral bridge test (p<0.05) [Table 4]. In paired comparisons, it was determined that the static trunk muscle endurance was significantly higher in the first group than in the second group, except for the right lateral bridge endurance (p=0.063) (p<0.05). There were statistically significant differences between the first and third groups in terms of static trunk muscle endurance (p<0.05). On the other hand, static trunk muscle endurance was found to be statistically similar between the second and third groups (p>0.05).

Table 2: Socio-demographic and physical characteristics of subjects.

Variables	Group 1 (n=17)	Group 2 (n=17)	Group 3 (n=17)	F	p value
Age, year, x ± SD	7.9 ± 0.8	8.1 ± 0.9	7.5 ± 0.6	3.154	0.052*
Height, cm, x ± SD	126.2 ± 7.8	131.5 ± 8.1	124.7 ± 6.1	3.972	**0.025***
Body weight, kg, x ± SD	26.7 ± 4.3	32.4 ± 8.1	26.3 ± 5.5	5.223	**0.009***
BMI, kg/m², x ± SD	16.6 ± 1.7	18.9 ± 3.3	16.9 ± 2.5	3.95	**0.027***
Leg length, cm, x ± SD	66.2 ± 4.1	70.9 ± 6.3	64.3 ± 4.9	7.296	**0.002***
Education, year, x ± SD	2.9 ± 0.8	3.1 ± 0.9	2.5 ± 0.6	3.154	0.052*
Dominant LE, n (%) Right	17 (100)	16 (94.1)	13 (76.5)		0.111¥
Left	-	1 (5.9)	4 (23.5)		

Table 3: Comparison of static trunk muscle endurance, balance, and explosive strength of subjects before the study, x ± SD.

Variables		Group 1 (n=17)	Group 2 (n=17)	Group 3 (n=17)	F	p value*
Static trunk muscle endurance tests	Flexion, sec	80.2 ± 61.0	38.9 ± 21.7	20.8 ± 8.5	11.058	**0.001**
	Extension, sec	28.3 ± 13.0	19.6 ± 6.6	12.8 ± 3.9	13.529	**0.001**
	Right lateral bridge, sec	20.1 ± 14.9	11.9 ± 5.1	11.6 ± 4.5	4.457	**0.017**
	Left lateral bridge, sec	17.0 ± 10.9	11.6 ± 4.7	11.4 ± 4.2	3.238	**0.048**
Y balance test	Anterior, cm	52.2 ± 6.9	53.1 ± 5.9	50.5 ± 4.0	0.893	0.416
	Posteromedial, cm	62.8 ± 11.1	61.0 ± 9.9	57.2 ± 7.6	1.497	0.234
	Posterolateral, cm	65.7 ± 17.6	63.9 ± 10.9	58.1 ± 8.7	1.584	0.216
	Composite, cm	90.9 ± 15.5	84.1 ± 8.9	93.1 ± 23.2	1.326	0.275
Flamingo balance test	Number of falls, falls/min	14.1 ± 3.7	11.8 ± 4.4	11.8 ± 6.0	1.255	0.294
Vertical jump test	Vertical jump height, cm	20.4 ± 4.5	19.6 ± 5.4	16.5 ± 3.9	3.34	**0.044**
Group 1= Gymnastics + Core stabilization training; Group 2= Gymnastics; Group 3= Control; *: One-Way Anova Test						

Table 4: Comparison of static trunk muscle endurance, balance, and explosive strength of subjects after the study, N=51, x ± SD, (% 95 CI).

Variables		Group 1 (n=17)	Group 2 (n=17)	Group 3 (n=17)	F	p value*
Static trunk muscle endurance tests	Flexion, sec	60.1± 10.2	49.6 ± 9.6	47.6 ± 9.9	6.565	**0.003**
	Extension, sec	34.6 ± 8.7	22.3 ± 7.8	18.6 ± 8.7	13.811	**0.001**
	Right lateral bridge, sec	23.6 ± 11.1	16.1 ± 11.1	14.9 ± 10.7	3.055	0.057
	Left lateral bridge, sec	20.6 ± 3.8	14.6 ± 3.9	12.6 ± 3.8	19.684	**0.001**
Y balance test	Anterior, cm	57.6 ± 6.8	55.6 ± 7.1	50.9 ± 6.8	4.322	**0.019**
	Posteromedial, cm	69.0 ± 11.9	66.4 ± 12.6	56.9 ± 12.0	4.873	**0.012**
	Posterolateral, cm	70.7 ± 13.4	69.1 ± 14.1	60.0 ± 13.5	3.095	0.055
	Composite, cm	96.9 ± 13.6	92.9 ± 14.4	84.2 ± 13.8	3.896	**0.027**

Flamingo balance test	Number of falls, falls/min	12.5 ± 5.2	12.2 ± 5.5	12.2 ± 5.3	0.014	0.986
Vertical jump test	Vertical jump height, cm	21.6 ± 2.1	19.2 ± 2.2	18.7 ± 2.1	8.714	**0.001**

Group 1= Gymnastics + Core stabilization training; Group 2= Gymnastics; Group 3= Control; *: General Linear Model

When the groups were compared in terms of dynamic balance, statistically significant differences were found between the groups except posterolateral reach distances (p = 0.055) [Table 4]. In the paired comparisons, no statistically significant difference was found between the first and second groups in terms of dynamic balance (p>0.05), while statistically significant differences were found between the first and third groups (p<0.05). When the second group and the third group were compared, there was a statistically significant difference in posteromedial reach distance (p = 0.034), but it was similar in all other directions (p>0.05). All groups were found to be statistically similar in terms of static balance (p>0.05) [Table 4]. After the study, statistically significant differences were found between groups in explosive strength (p<0.05) [Table 4]. When the groups were compared in terms of explosive strength, although there were statistically significant differences in favor of the first group (p<0.05), the second and third groups were similar in terms of this variable (p = 0.580). Statistically significant differences were found between the static trunk muscle endurance, static and dynamic balances, and explosive strengths of the participants in the first group before and after the study (p<0.05). The lower and upper limit values of 95% CI of the difference supported this result. The effect sizes of these variables were large (r≥0.5) [Table 5].

Table 5: The effect sizes of the trunk muscles endurance, balance and explosive strength (r).

Variables	Group 1			Group 2			Group 3		
	t	p	r	t	p	r	t	p	r
Flexion test	-4.148	**0,001**	0.7	-1.89	**0,077**	0.4	-0.894	0,385	0.2
Extension test	-4.514	**0,000**	0.7	-0.043	**0,043**	0.5	1.295	0,214	0.3
Right lateral bridge test	-2.532	**0,022**	0.5	-1.004	0,030	0.2	2.895	**0,011**	0.6
Left lateral bridge test	-5.548	**0,000**	0.8	-2.212	**0,042**	0.5	1.886	0,078	0.4
Y balance test anterior	-4.233	**0,001**	0.7	-2.978	**0,009**	0.6	0.881	0,391	0.2
Y balance test Posteromedial	-3.53	**0,003**	0.7	-3.371	**0,004**	0.6	1.19	0,251	0.3
Y balance test posterolateral	-3.583	**0,002**	0.7	-3.311	**0,004**	0.6	-0.592	0,592	0.1
Y balance test composite	-3.991	**0,001**	0.7	-3.496	**0,003**	0.7	1.541	0,143	0.4
Flamingo balance test	3.237	**0,005**	0.6	-0.643	**0,529**	0.2	-1.126	0,126	0.4
Vertical jump test	-4.016	**0,001**	0.7	-1.1	**0,288**	0.3	-0.309	0,761	0.1

Group 1= Gymnastics + Core stabilization training; Group 2= Gymnastics; Group 3= Control

Extensor and left lateral static trunk muscle endurance and dynamic balances of the second group were significantly different after the study (p<0.05). The lower and upper limit values of 95% CI of the difference supported this result. The clinical effect for these variables was large (r≥0.5). Although there was no statistically significant change in flexor static trunk muscle endurance, the clinical effect was calculated as medium-large (r = 0.4). The effect size for the other variables was between small-medium and medium (r≤0.3) (Table 5). In the third group, there was a statistically significant decrease in right lateral trunk endurance after the study (p = 0.011). The effect size of the change for this value was large (r = 0.6). In this group, there was no statistically significant change in the Y balance test, Flamingo balance test and Vertical jump test results (p>0.05) [Table 5].

Discussion

In this study, the core stabilization exercise programme applied in addition to the 8-week artistic gymnastics training was found to be effective in improving the trunk muscle endurance, static balance, dynamic balance, explosive strength and thus athletic performance. Basic motor skills develop rapidly between the ages of 5-8. As children find new solutions for effective movement patterns, these skills continue to improve and mature [11]. The most significant changes in motor development for postural control occur between the ages of 7-10. When children reach 10 years of age, they can perform challenging balance activities on their single extremities adequately [12]. In this study, the 7-9 age range was chosen in our study by considering these developmental steps in balance and the ages of children who regularly attend gymnastics training in Northern Cyprus. There are some physical and physiological differences between genders in children. These differences become apparent after puberty and can directly affect performance. Although it is stated that the differences seen before puberty are mostly due to hereditary causes, leg and trunk flexibility is higher in girls of all ages. However, it has been shown that there are relatively lower differences in body fat ratio [13]. The increase in body fat ratio causes slower performance at any age [14]. Gender in primary school children is an element that must be taken into consideration when measuring postural oscillations. It has been shown that males have more postural oscillations than females [12]. Therefore, it is stated that men are successful in sports that require strength and women in sports branches that require more flexibility such as gymnastics. For these reasons, only girls were included in the study.

In gymnastics, where biomechanical properties play an important role, athletes need to have developed strong muscle structure and good neuromuscular coordination [15]. As a result of weakness in the muscles or inadequate endurance, forces cannot be transferred properly along the kinetic chain and problems arise in the transfer of the resulting power outputs [16]. Core muscle fatigue reduces the dynamic stability of the trunk and causes loss of postural control [17,18]. In a study by Pomije MK., the effects of lumbopelvic stabilization training in non-elite gymnasts aged 9-17 years were examined. Stabilization training was given to the treatment group and yoga training was given to the participants in the other group. After training, the authors found that there was no difference in the right lateral trunk endurance. Many movements are used in both gymnastics and required bilateral muscle activity. Gymnastics is not considered a one-sided dominant sport, but gymnasts have a favorite side to perform movements during performance. Therefore, the authors thought that the tendency of athletes to perform movements with one side of their choice during performance due to there is no difference in the right lateral trunk endurance [19]. Similarly, in the present study, the results of the right lateral trunk muscle endurance were found to be similar to the group. On the other hand, in terms of clinical effect, core stabilization exercise in addition to artistic gymnastics was found to be more effective than just artistic gymnastics. As is known, during lateral bridge exercises, mainly the lateral core muscles are exercised. In a study by Juker et al., it was reported that during the lateral bridge tests, myoelectric activity of oblique abdominals and small amount of hip flexors were measured. Depending on the weakness of the hip flexors, the test is adversely affected by the disruption of the proper posture during the test and the fall of the hip [20]. In contrast to the trunk flexor and extensor tests, the whole-body weight is placed on the forearm in the lateral bridge test. Although athletes tried to maintain a proper posture by activation of the lateral core muscles, it is thought that the strength and endurance of the muscles around the shoulder may have influenced the results. In our study, it is not possible to make a definitive judgment about the effects of the muscles and hip flexors because of the lack of any information about the preferred side of the athletes during their training. Methodological differences between studies should also be taken into consideration when interpreting the results.

In a study performed by Schilling et al., two groups were formed, and one group was given isometric endurance exercises while the other group received isotonic strengthening exercises. Sit-up, cross curl-up, and trunk extension exercises were performed twice a week for 6 weeks. As a result of the study, it was stated that both exercise training provided positive improvements in core endurance and lower extremity strength, but they were not superior to each other [21]. In our study, both isotonic and isometric exercises were included in the 8-week exercise training programme. There was a statistically significant increase in core endurance compared to the other groups except right lateral trunk endurance. The core stabilization exercises, which were added to artistic gymnastics training, had a large clinical effect on increasing trunk flexor and extensor, and right and left lateral static trunk muscle endurance.

In gymnastics, balance skill which is the basis of many movements is very important. Dynamic balance mainly affects performance during ascents, while static balance becomes prominent during descents [22]. In a study examining the effects of a six-week core stabilization exercise training programme on core endurance and dynamic balance, 13 healthy athletes with an average age of 15 were included in the study. Trunk endurance and dynamic balance significantly improved at the end of the six weeks of training [23]. In the development of dynamic balance which is one of the secondary outcome measures of our study, both artistic gymnastics and core stabilization exercise training added to this programme showed similar clinical effects. This change was much greater in both groups than in control. Therefore, it can be stated that artistic gymnastics training is very important in improving dynamic balance even if core stabilization exercises are not applied.

Mills et al. examined the effects of a training programme to improve core stabilization on lumbopelvic stability and athletic performance. Thirty volleyball players and basketball players aged between 18 and 23 participated in the study. The authors stated that agility, lower extremity strength, and static balance measurements are indicative of athletic performance. The results showed that the training had positive effects on lumbopelvic stabilization in the lumbopelvic stabilization training group. When the comparison between the groups was made, the results between treatment and pseudo-treatment groups were similar in terms of stabilization. On the other hand, differences in agility and lower extremity strength were obtained between the groups. Although static balance was found to be improved after treatment in all groups, it was shown that there was no difference between the groups [24]. Similar to the study of Mills et al., in our study, static stabilization exercises added to artistic gymnastics training were clinically more effective than artistic gymnastics training, although static balance was statistically similar in all three groups at the end of 8 weeks. Moreover, within-group comparisons, there was no improvement in static balance after the study, and some deterioration, although not statistically significant, was observed in the subjects in control group. Therefore, adding core stabilization training to gymnastics training is thought to be beneficial for improving static balance. Although these results are mostly consistent with our study, it should be noted that there are methodological differences between the two studies and the pseudo-treatment applied by Mills et al. is actually intended to strengthen global core muscles.

It is known that physical performance can be improved by strength and endurance training in many sports [25,26,27]. It has been emphasized that core stabilization exercise training in participants from different sports branches may have beneficial effects on improving athletic performance, but more research is needed [28]. In our study, athletic performance could not be directly measured due to the lack of a gold standard test for gymnastics. However, because of the frequent jumps in the gymnastics branch, the explosive strength was evaluated by the vertical jump test, which indirectly gave information about the performance. When the results were examined, it was found that there was a significant increase in the explosive strength of the children who performed core stabilization exercises in addition to artistic gymnastics, compared to the children who did not perform core stabilization exercises. Therefore, it is thought that performance can be improved by adding core stabilization exercise programmes to artistic gymnastics training programmes.

Conclusion

Our results show that the addition of core stabilization exercises into the training programmes of children attending in artistic gymnastics training is effective in increasing static trunk muscle endurance, improving static and dynamic balance and improving athletic performance. With the improvement of core endurance, it is foreseen that the movements can be performed in a more controlled manner, a better sporting performance can be achieved, and children will be protected from injuries. For this reason, it is clear that the addition of exercises aimed at strengthening the core muscles in the training programme of the athletes who want to improve themselves in the gymnastics field, will improve the static and dynamic balance, which is important in gymnastics, and increase the athletes' performance. Furthermore, parents are encouraged to direct their children to artistic gymnastics training to support motor development even if they are not professional athletes. In the future, it will be possible to generalize the results to all children in this age group with studies including boys.

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Conflict of interest

None.

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