ORIGINAL ARTICLE

Improving the physical components of gymnastics athletes following long-term circuit training with static and dynamic core stabilization

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim Core stability is a fundamental aspect of gymnastics performance, essential for balance, flexibility, and overall strength. This study aims to investigate the effects of long-term circuit training with static and dynamic core stabilization on physical components in gymnasts.

Material and Methods This study used a randomized controlled trial (RCT) design. A total of 42 participants were randomly assigned to three groups: a control group (CTR, n=14), a static core stabilization group (CSS, n=14), and a dynamic core stabilization group (CSD, n=14). The intervention programs for static and dynamic core stabilization included six distinct exercises. These exercises were performed three times per week over an 8-week period. Data were collected at two time points: pretest and posttest. Physical components assessed included flexibility, balance, and the strength of the abdominal, back, leg, and arm muscles. Data analysis was conducted using a paired sample t-test with the significance level set at 5%.

Results The results showed significant improvements in flexibility (cm), balance (s), back muscle strength (kg), abdominal muscle strength (repetitions), and arm muscle strength (repetitions) in the core stabilization groups between the pretest and posttest ($p \leqslant 0.05$). However, no significant changes were observed in leg muscle strength (kg) ($p \geqslant 0.05$). When comparing groups, significant differences were noted in balance (s), back muscle strength (kg), abdominal muscle strength (repetitions), and arm muscle strength (repetitions) ($p \leqslant 0.05$). Flexibility (cm) and leg muscle strength (kg) did not show significant differences between groups ($p \geqslant 0.05$).

Conclusions The study highlights the importance of incorporating core stabilization exercises into circuit training programs for gymnasts. Both static and dynamic approaches to core stabilization provide valuable strategies for optimizing physical conditioning and enhancing athletic performance. These findings can inform the development of evidence-based training protocols aimed at improving key physical attributes critical for gymnastics.

Keywords: core stabilization training, gymnastic, physical components, physical performance

Introduction

Gymnastics demands athletes to achieve exceptional levels of flexibility, balance, and muscular strength, all of which rely heavily on core stability. Despite the acknowledged importance of core-focused training, identifying optimal methods to develop these attributes remains a challenge, necessitating the search for more effective solutions. This pursuit is particularly critical in gymnastics, a sport that combines the demands of agility, strength, flexibility, and balance into a single, highly dynamic discipline [1]. Gymnasts are required to develop comprehensive abilities to integrate upper and lower extremity muscle strength, with core muscles serving as the body's center of stability [2]. These core muscles, which encompass the muscles surrounding the spine, abdomen, lower back, and gluteal region, are crucial for maintaining postural balance and stability during dynamic and static movements such as flips, handstands, and landings [3]. Core strength and stability play a vital role in enhancing postural control and lumbopelvic stability, which are essential for ensuring biomechanical efficiency during complex gymnastics movements [4].

Core stabilization training is a method designed to improve core muscle strength and enhance body balance [5]. In gymnastics, core stabilization exercises are essential because movements such as longitudinal rotations, jumps, and landings demand dynamic postural stability to maintain balance [6]. These exercises, whether static or dynamic, improve stability by strengthening the trunk, abdominal, and

doi:10.15561/26649837.2024.0605

back muscles, which are critical for balance during activity [7]. Core stabilization training includes two primary components: static and dynamic movements [8]. Static exercises focus on maintaining posture under load, while dynamic exercises develop the ability to sustain stability during movements involving positional changes, rotation, or weight shifts [9]. Research has shown that combining static and dynamic core stabilization exercises significantly improves muscle strength, flexibility, and postural balance in athletes, which are key to enhancing gymnasts' physical performance [10].

The role of core muscles in injury prevention has been extensively highlighted in the literature. Golsefidi [11] emphasizes that regular core stabilization exercises enhance lumbopelvic stability, thereby reducing stress on the spine and lowering the risk of lower back injuries. Additionally, strong core muscles contribute to proper body alignment, ensuring more efficient force distribution between the upper and lower extremities during explosive gymnastics movements such as flips and landings [12].

Circuit training integrates various exercises into a single session to enhance muscle strength, endurance, and coordination [13]. Typically, it involves multiple stations that incorporate both static and dynamic core stabilization exercises, offering variety to sustain athletes' motivation while simultaneously strengthening core muscles, improving balance, and enhancing flexibility [14]. Exercises such as prone bridging on the elbow, supine bridge lifts with arms at the side, and dynamic hamstring stretches impose varied demands on the core, promoting increased strength and postural stability [15]. Moreover, circuit training that includes core stabilization exercises boosts neuromuscular capacity by strengthening the connection between the nervous system and muscles, leading to greater motor activation during contractions [16]. This is particularly critical in gymnastics, where complex movements like rotations and jumps demand rapid muscle responses to adjust posture and ensure precise control [11]. By integrating core stabilization into circuit training, athletes benefit from a diverse and comprehensive approach that improves motivation and supports overall physical performance development [17, 18].

The analysis of previous research highlights the importance of core stabilization in improving physical performance and preventing injuries in gymnastics. Studies show that both static and dynamic core stabilization exercises offer significant benefits. Integrating these exercises into circuit training has been found to enhance strength, balance, and flexibility. Additionally, circuit training improves neuromuscular coordination and reduces the risk of injury. However, the most effective methods for optimizing these benefits remain unclear. This study aims to investigate the effects of long-term circuit training with static and dynamic core stabilization on physical components in gymnasts.

Materials and Methods

Participants

The study population comprised students from the Department of Sports Coaching Education, Faculty of Sport and Health Science, Universitas Negeri Surabaya (Indonesia). Out of 140 available students, 42 were selected using random sampling techniques. These participants were assigned to three groups through ordinal pairing: a control group (CTR, n=14), a static core stabilization group (CSS, n=14), and a dynamic core stabilization group (CSD, n=14). The study followed a randomized controlled trial (RCT) design with a true experimental approach and a pretest-posttest control group format. Data were collected during both the pretest and posttest phases, measuring several physical components (Table 1).

Research Design

The static core stabilization program included six exercises:

1. Hip Flexor Stretch,
2. Prone Bridging on Elbow,
3. Prone Cobras,
4. Side Bridging on Elbow,
5. Supine Butt Lift Arm in Chest,
6. Prone Bridging Around the World with Parallel Hands.

The dynamic core stabilization program also comprised six exercises:

1. Dynamic Hamstring Stretch,
2. Prone Bridging on Elbow with Leg Extension,
3. Supermans,
4. Side Bridging on Elbow with Single Leg Hip Abduction,
5. Supine Butt Lift Arm at Side,
6. Prone Bridging Around the World with Cross Arm.

Both training programs were conducted three times per week over an 8-week period. Heart rate was monitored throughout the intervention using a Polar H10 heart rate monitor chest strap.

Statistical analysis

Descriptive statistics, including minimum and maximum values, means, standard deviations, and frequency distributions, were calculated to summarize the data. The Shapiro-Wilk test was used to assess data normality, while Levene's test was applied to evaluate homogeneity of variance. Hypothesis testing was conducted using paired sample t-tests and one-way ANOVA. Post hoc analyses were performed using least significant difference (LSD) tests to identify specific group differences. The significance level was set at 5%. All statistical analyses were conducted using IBM SPSS Statistics V21.0 for Windows 10.

Results

The statistical analysis of the general characteristics between the static core stabilization group (CSS) and the dynamic core stabilization group (CSD) showed no significant differences in any parameters ($p \geqslant 0.05$, table 2). Detailed results of the physical component analysis, including flexibility, balance, and strength of the abdominal, back, leg, and arm muscles, between the pretest and posttest are summarized in Table 3 and Figure 1.

Table 1. Summary of Variables, Instruments, and Tools

Parameters	Instrument Test	Unit	References
Balance	Balance Beam	second	[19]
Flexibility	Sit and Reach Test	cm	[20]
Abdominal muscle strength	Sit Up Test (30 s)	times	[21]
Back Muscle Strength	Back Dynamometer	kg	[22]
Leg Muscle Strength	Leg Dynamometer	kg	
Arm Muscle Strength	Push Up Fitness Test (30 s)	times	[23]

Table 2. General characteristics of the participants

Parameters	CTR; n=14	CSS; n=14	CSD; n=14	p value
Age (yrs)	20.29 ± 0.83	20.28 ± 0.73	20.86 ± 0.87	0.110
Heart rate (bpm)	68.00 ± 8.88	72.36 ± 9.98	68.86 ± 9.82	0.450
Systolic blood pressure (mmHg)	116.57 ± 4.55	115.14 ± 7.36	114.29 ± 6.46	0.622
Diastolic blood pressure (mmHg)	81.57 ± 3.16	79.57 ± 8.38	79.29 ± 6.16	0.581
Body temperature (°C)	36.51 ± 0.39	36.60 ± 0.44	36.71 ± 0.43	0.451
Body weight (kg)	60.00 ± 5.59	59.14 ± 3.66	59.00 ± 5.12	0.217
Body height (cm)	168.00 ± 4.00	165.00 ± 3.00	167.00 ± 5.00	0.841
Body mass index (kg/m²)	21.34 ± 1.28	21.74 ± 0.98	21.19 ± 0.77	0.352

Note. CTR: Control group; CSS: Core stabilization static group; CSD: Core stabilization dynamic group. The p values were calculated using one-way ANOVA. Data are presented as means ± SD.

Table 3. Comparison of gymnasts' physical components among the three groups

Parameters	CTR; n=14	CSS; n=14	CSD; n=14	p value
Pre-Flexibility (cm)	36.79 ± 8.25	37.79 ± 6.01	37.50 ± 3.21	0.908
Pre-Balance (s)	28.57 ± 23.11	23.00 ± 11.46	34.07 ± 26.72	0.402
Pre-Back Muscle Strength (kg)	96.24 ± 20.16	96.25 ± 19.71	98.04 ± 17.68	0.960
Pre-Leg Muscle Strength (kg)	101.33 ± 36.94	123.00 ± 30.56	117.11 ± 42.47	0.288
Pre-Abdominal Muscle Strength (times)	25.43 ± 2.98	24.43 ± 3.59	23.29 ± 4.07	0.295
Pre-Arm Muscle Strength (times)	28.57 ± 5.87	29.86 ± 7.89	28.79 ± 8.77	0.892
Post-Flexibility (cm)	37.36 ± 3.37	38.32 ± 6.04	39.79 ± 3.61	0.366
Post-Balance (s)	34.22 ± 26.65	31.43 ± 12.05	64.00 ± 41.82*†	0.010
Post-Back Muscle Strength (kg)	94.87 ± 22.77	111.50 ± 10.63*	106.93 ± 11.69*	0.025
Post-Leg Muscle Strength (kg)	112.93 ± 45.96	115.04 ± 17.98	126.07 ± 25.26	0.512
Post-Abdominal Muscle Strength (times)	23.22 ± 4.079	24.57 ± 2.96	26.86 ± 3.33*	0.028
Post-Arm Muscle Strength (times)	27.72 ± 9.86	35.07 ± 9.91*	36.72 ± 8.80*	0.039
Δ-Flexibility (cm)	0.57 ± 7.51	0.54 ± 3.16	2.29 ± 1.68	0.550
Δ-Balance (s)	5.65 ± 16.34	8.43 ± 8.10	29.93 ± 25.40*†	0.002
Δ-Back Muscle Strength (kg)	-1.37 ± 26.85	15.25 ± 15.99	8.89 ± 13.97	0.094
Δ-Leg Muscle Strength (kg)	11.60 ± 48.71	-7.97 ± 25.77	8.96 ± 32.93	0.328
Δ-Abdominal Muscle Strength (times)	-2.22 ± 4.69	0.14 ± 2.82	3.57 ± 2.62*†	0.000
Δ-Arm Muscle Strength (times)	-0.86 ± 8.68	5.22 ± 5.35*	7.93 ± 2.99*	0.002

Note. *Significant compared to CTR ($p \leqslant 0.05$); †Significant compared to CSS ($p \leqslant 0.05$). The p values were obtained using the least significant difference (LSD) post hoc test following one-way ANOVA.

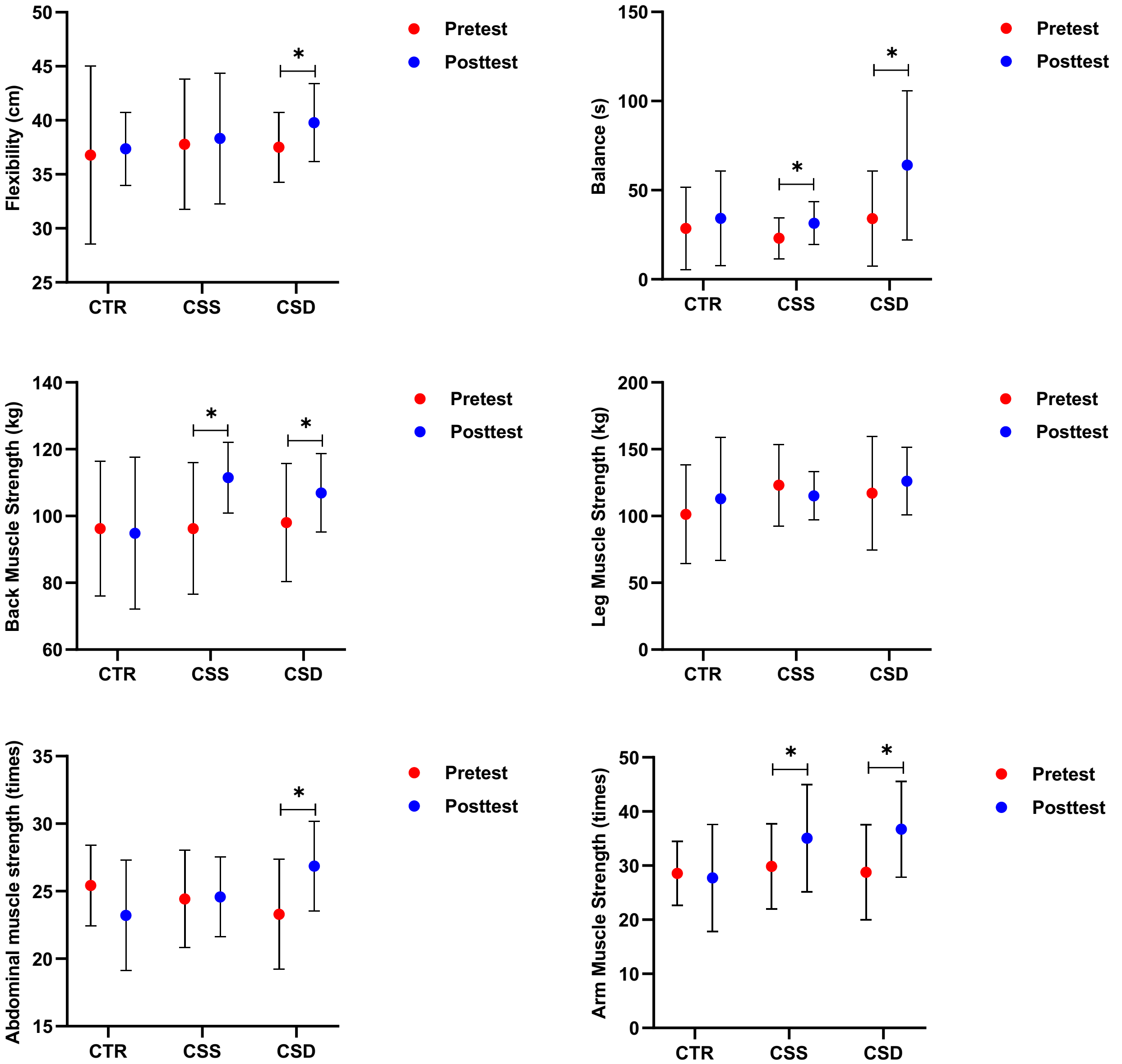

Figure 1. Comparison of Gymnasts' Physical Components between the Pretest and Posttest in Each Group: Note. * indicates significance at the pretest ($p \leqslant 0.05$). The p value was obtained via paired sample t tests.

Discussion

The findings of this study show that incorporating static and dynamic core stabilization exercises into circuit training significantly enhances flexibility, balance, and the strength of key muscle groups, including the abdominal, back, leg, and arm muscles, in gymnasts. These improvements reflect the combined effects of neuromuscular activation and physiological adaptations, involving the targeted activation of type I and type II muscle fibers during static and dynamic exercises. Static exercises, such as prone bridging, improve isometric stability by engaging type I fibers. In contrast, dynamic exercises, like prone bridging with leg extensions, activate type II fibers, which are crucial for explosive strength in movements like flips and jumps [24, 25]. By integrating both approaches, this study addresses a notable gap in the literature, as prior research has often focused solely on either static or dynamic exercises without examining their synergistic potential, especially in gymnastics contexts.

The enhanced lumbopelvic stability achieved through this combined training method improves force distribution between the upper and lower extremities. This is a critical factor for high-impact gymnastics movements such as jumps, flips, and rotations. Improved stability not only enhances performance but also reduces spinal pressure. This reduction addresses a major risk factor for lower back injuries, which are common in gymnasts [12, 26]. While earlier studies have highlighted the general benefits of core strength, this research makes a unique contribution. It directly links lumbopelvic stability to both performance enhancement and injury prevention, offering a dual benefit.

Furthermore, the dynamic exercises used in this study improve proprioception. This allows gymnasts to maintain balance during complex movements like landings and rotations. Enhanced proprioception increases technical precision and reduces the risk of injury. It does so by promoting better body alignment during high-speed maneuvers [18, 27]. Unlike previous studies focused on static balance or simple motor tasks, these findings provide new insights. They show how proprioceptive gains translate into sport-specific performance outcomes, particularly in gymnastics.

From a physiological perspective, this study highlights that core stabilization exercises stimulate mitochondrial adaptation in core muscle fibers. This adaptation enhances energy efficiency and improves endurance during repetitive, high-intensity routines. Such a mechanism ensures that muscles can sustain performance even under fatigue, a critical requirement in gymnastics competitions [28, 29]. These findings expand the understanding of the metabolic benefits of core training, an area that is still underexplored in the context of gymnastics-specific demands. By integrating physiological, neuromuscular, and proprioceptive benefits, this research underscores the holistic impact of combining static and dynamic core stabilization exercises in circuit training.

Despite the promising findings, this study has several limitations. The eight-week intervention period may have been too short to capture long-term adaptations in neuromuscular and biomechanical performance. Longitudinal studies suggest that extended training durations are necessary to fully realize these benefits [5]. Another limitation is the relatively small sample size of 42 participants. While sufficient for detecting short-term improvements, this limits the generalizability of the results to the broader gymnastics population. Future research should address these issues by including larger and more diverse samples. It should also incorporate advanced biomechanical analyses, such as measurements of spinal posture, body alignment, and muscle fascia thickness. These additions would provide a more comprehensive understanding of the training's effects.

The implications of this research are significant for both gymnastics training and rehabilitation practices. Incorporating core stabilization exercises into circuit training routines not only enhances flexibility, balance, and muscle strength but also introduces varied and challenging activities that help sustain athlete motivation [17, 18]. These exercises could be adopted as part of daily training regimens to build a foundation for long-term performance and physical health [3, 30, 31]. Moreover, they hold significant potential for clinical applications, as they could be adapted into rehabilitation programs for athletes recovering from lower back injuries, helping prevent recurrence and facilitating quicker recovery timelines [32]. Unlike traditional weight training or plyometric exercises, this integrated approach enhances postural control and dynamic stability, making it particularly suited for the complex demands of gymnastics.

This study demonstrates that integrating static and dynamic core stabilization exercises in circuit training enhances postural stability, balance, and core strength in gymnasts. These findings contribute to a deeper understanding of effective training methods by highlighting the complementary benefits of static and dynamic approaches. The research provides a basis for refining gymnastics training programs to improve athletic performance and support long-term physical health.

Limitations of the Study

While the study provides valuable insights, several limitations should be noted. Although an eight-week intervention is a commonly accepted duration in training studies, longer-term research could help to capture potential adaptations that may emerge over extended periods of training. Additionally, while the sample size of 42 participants meets the requirements for robust statistical analysis, future studies with larger and more diverse participant groups could further validate the findings and increase their applicability to broader gymnastics populations. Finally, the study did not incorporate advanced biomechanical assessments, such as analyses of spinal posture or muscle fascia characteristics, which could offer a more detailed understanding of the observed performance improvements. Addressing these aspects in future research could provide a more comprehensive evaluation of the effects of combined static and dynamic core stabilization training.

Conclusions

Integrating static and dynamic core stabilization exercises into circuit training represents a promising approach for enhancing the physical capabilities of gymnasts. This comprehensive method supports the simultaneous development of key physical attributes, meeting the specific demands of gymnastics. By combining the benefits of both exercise types, it establishes a foundation for effective adaptation within the training process.

This study contributes to the understanding of training methods aimed at improving functional performance and preventing injuries. The findings may serve as a valuable resource for coaches, sports physicians, and rehabilitation specialists in designing individualized programs that focus on the long-term development and health maintenance of athletes.

Conflicts of Interest

The authors declare no conflict of interest in this study.

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Cite this article as:

Wijaya FJM, Kartiko DC, Pranoto A, Kusuma IDMAW, Phanpheng Y. Improving the physical components of gymnastics athletes following long-term circuit training with static and dynamic core stabilization. *Pedagogy of Physical Culture and Sports,* 2024;28(6):509–515.
https://doi.org/10.15561/26649837.2024.0605

Received: 09.10.2024
Accepted: 28.11.2024; Published: 30.12.2024