Research Paper

Core Stability Training Improves Movement Quality, Balance, and Performance in Basketball Players

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ABSTRACT

Purpose: A strong core is a crucial prerequisite for participation in many sports. This study aimed to investigate the effect of core stability exercises on functional movement screen (FMS) scores, balance, and performance in elite basketball players.

Methods: Thirty-four adult male elite basketball players were divided into core exercise and control groups, with the core exercise group performing an eight-week core stability exercise protocol. Balance, movement patterns, and performance were evaluated using the Y-balance test (YBT), the FMS, the Single-Leg Hop Test, the Zigzag Triple-Hop Test, the Davies Test, and the Square Hop Test, respectively. Data were analyzed using descriptive statistics, followed by analysis of covariance (ANCOVA) for parametric data and Quade's test for non-parametric data.

Results: The findings indicated a significant difference between the core exercise and control groups in total FMS score (P=0.001), single-leg hop test (P=0.001), zigzag triple hop test (P=0.001), dominant upper limb balance scores (P=0.001), non-dominant upper limb balance scores (P=0.001), square hop test (P=0.001), and Davies closed kinetic chain (CKC) test (P=0.001).

Conclusion: The current study's results showed that after eight weeks of core stability exercises, elite basketball players experienced significant improvements in FMS scores, balance, and performance. These findings highlight the positive effect of core-focused exercises on enhancing movement efficiency and athletic performance, which may have important implications for reducing injury risk in elite athletes.

Keywords:
Core stability, Performance, Balance, Basketball

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Highlights

- Core stability training improved FMS scores in elite basketball players.

- Improved movement efficiency may contribute to reduced injury risk.

- Balance improved in both dominant and non-dominant limbs after core stability exercises.

Plain Language Summary

According to this study, core stability exercises can considerably enhance elite male basketball players' movement quality, balance, and athletic performance. The players' performance on movement tests, such as deep squats, lunges, shoulder mobility, and balancing activities have improved after completing an eight-week core training program. Compared to individuals who did not practice the core exercises, they also demonstrated better results on performance-based assessments. These findings demonstrate the advantages of core-focused training for athletes looking to improve their performance and lower their risk of injury.

Introduction

Today, with the increasing importance of sports at all levels of society, attention to sports injuries has become more prominent [1]. Injury is inevitable in every sport, and each sport has specific injuries. Basketball, which was created more than a century ago by James Naismith in the United States, has become one of the most popular sports in the world [2]. Basketball is a complex, high-impact sport, with an estimated 11% of the world's population playing basketball [3]. With the increasing number of basketball players, the rate of injury has also increased, with a significant percentage of reported injuries occurring in the lower extremities (between 13% and 44%) [3, 4]. A review study that examined 12,000 reported injuries in basketball showed that, regardless of gender, more injuries occur in the lower extremities (63.7% of injuries), and the prevalence of injuries in elite athletes was reported to be 64.7% [5]. In addition, injuries to the upper extremities and trunk may also occur in basketball, as this sport involves repeated body contact and use of the upper extremities [6]. Injury prevention and risk reduction are more crucial than treatment, and screening before participation in an activity can address an important part of this issue [7]. Researchers have developed methods and tools to evaluate movement patterns for injury prevention, one of which is the functional movement screen (FMS), which can demonstrate the quality of functional movement patterns and identify individuals at risk [8, 9]. A study revealed that DS and HS scores may be associated with injuries in basketball players [10].

Core stability is the ability of core muscles to maintain spinal and pelvic stability during dynamic movements [11]. A strong core is a crucial prerequisite for practicing sports, such as track and field, basketball, and football [12]. During basketball activities, such as dribbling, boxing out, and rebounding, which involve sudden and specific movements, the core is responsible for maintaining stability and the biomechanical linkage between the upper and lower limbs [13]. The power generated in basketball-specific movements, such as shooting and layups, passes through the core of the body [14]. Core muscles minimize disturbances created during upper limb movements, enabling better balance during dynamic activities and thereby enhancing shooting performance without adding extra burden to the upper limbs [15]. Weakness or lack of sufficient coordination in the core stability muscles can lead to disruption of movement patterns, compensatory movement patterns, overuse, and ultimately injury [16]. Therefore, it can be concluded that weakness in stabilizing core muscles can have a negative effect on movement patterns [17]. In addition to having a strong core, improving balance control is an important goal in sports and exercise, as good balance strongly correlated with improving athletes' performance and a negative correlation with upper and lower limb injuries [18]. A review by Luo et al. (2022) showed that core training can potentially improve performance in athletes across various sports, including football, handball, basketball, and golf [19].

Several studies have separately investigated the effect of core stability exercises on FMS scores, balance, and upper and lower limb performance in basketball players [20-26]. Also, most existing literature has either focused on recreational or relied on adolescent athletes or employed generalized fitness protocols that may not capture the unique physical demands of high-level basketball, such as rapid changes of direction, explosive jumping, and sustained isometric control during competitions. Given the growing emphasis on evidence-based training approaches in elite sports, there is a pressing need to investigate how core stability training protocols influence FMS scores, balance, and performance in elite athletes. Addressing this gap enhances training and rehabilitation strategies, improving injury reduction and performance optimization in competitive basketball players.

Materials and Methods

This study included 34 elite basketball players who were selected using convenience sampling and divided into core exercises (n=17) and control groups (n=17). Using G*Power software, version 3.1, considering an effect size of 0.50, a significance level of 0.05, and a statistical power of 0.80, the sample size was calculated to be 17 in each group. The inclusion criteria included an age range of 18-30, a minimum of three years of professional basketball, an absence of musculoskeletal injuries in the upper and lower limbs within the past six months [27], no history of surgery in the upper and lower limbs in the past six months, absence of significant musculoskeletal abnormalities, no simultaneous participation in other research or exercise programs, and no history of neuropathy or use of medication affecting the body's nervous and motor systems. The exclusion criteria included injury during the research, non-compliance with the training protocol, withdrawal from the study, failure to complete the research process, and absence from two consecutive and three intermittent training sessions. Initially, in accordance with the Declaration of Helsinki, participants were fully informed about all aspects of the study, and written consent was obtained. They were also assured that the examiner would take appropriate measures in case any issues arose during the testing process. All assessments were conducted by certified corrective exercise specialists with extensive experience in evaluating functional movement and athletic performance. Each test was clearly explained to the participants beforehand. A comprehensive overview of the procedures was presented before the tests. All measurements were conducted three times, and the average of these measurements was utilized as the final data for analysis.

FMS test

The FMS kit was utilized to assess FMS scores. The FMS consists of seven movement tests: Deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push-up (TSPU), and rotary stability (RS) [28, 29]. Each movement test is scored on a scale of zero to three, with higher scores indicating better performance. The scoring criteria are as follows: A score of three is awarded for a complete and correct movement; a score of two indicates compensation during the movement; a score of one is given when the movement cannot be completed; and a score of zero is assigned if pain is experienced during the test [30, 31]. To calculate the total FMS score, the individual scores of all tests were summed. The total score can range from zero, indicating pain in all movement tests, to 21, representing perfect performance across all tests. Studies have reported moderate intra-rater and inter-rater reliability for FMS tests [32, 33]. Additionally, Chorba et al. (2010) demonstrated sufficient capability of the FMS to predict injury [34]. To ensure accurate scoring, the examiner must observe and evaluate the participant from all anterior, posterior, and lateral views during the tests.

Single-leg hop test

This assessment uses a 3-meter-long narrow measuring tape placed on the floor. The participant stands on their dominant leg with the toes aligned just behind the starting line. The procedure involves executing a maximal forward hop on one leg, landing on the same foot, and maintaining balance for a minimum of two seconds. Arm movements are permitted to help balance if needed. After 2–3 practice trials, the participant performs a full single-leg hop using the dominant leg, and the distance jumped is measured. Previous studies have reported high reliability for this test, with intraclass correlation coefficients exceeding 0.85 [35].

Davies closed kinetic chain (CKC) test

In the Davies CKC upper extremity stability test, two parallel tape lines were positioned on the floor, separated by a distance of three feet. Participants assumed a push-up position and were directed to rapidly alternate their hand movements between the lines, making contact with each line in succession. They were advised to maintain a straight trunk and minimize movement of the head and torso. After a warm-up trial, three 15-second maximum-effort trials were performed, each separated by a 45-second rest period. The average number of touches across the three trials was calculated for analysis [36]. The test has demonstrated high test-re-test reliability, reported at 0.92 [37].

Y-balance test (YBT)

The YBT is a standardized method for objectively evaluating dynamic balance during functional movement. Participants placed themselves at the center of the YBT kit and are instructed to reach as far as possible in three directions—anterior, posterolateral, and posteromedial—while keeping the stance foot aligned with the designated markers. After each reach, they return to the starting position. The test is performed on both legs. The furthest point of contact, typically the toe, on the measuring stick indicates the maximum reach. Trials in which balance is lost, the stance foot shifts, or the reach indicator is struck are considered invalid. A composite score is calculated by summing the reach distances in all three directions, dividing by three times the leg length, and multiplying by 100 to obtain a percentage. Leg length is assessed with the participant in a supine position, measuring from the anterior superior iliac spine to the most distal point of the medial malleolus, utilizing a measuring tape [38]. The evaluation of a person's preferred leg for kicking a ball serves to identify the dominant lower limb. YBT demonstrates strong inter-rater and test-retest reliability [39].

Zigzag triple hop test

In this test, the participant stood on the testing leg and performed three consecutive zigzag hops over a line with a width of 15 cm. The movement was executed in a zigzag pattern, and the maximum total distance covered across the three hops was recorded as the performance score. The trial was considered invalid and repeated if the participant touched the ground with the non-testing leg or failed to completely clear the width of the tape line during any of the hops [40]. The test has demonstrated high intra-rater reliability, reported at 0.97 [41].

Square hop test

In this test, the participant performed clockwise hops on a single leg outside the perimeter of a 40×40 cm square for 30 seconds. The participant moved continuously clockwise, hopping over each side of the square. Each time a full revolution was completed, the participant announced it aloud while the examiner discreetly noted any instances where the leg landed on the line during the test. At the end of 30 seconds, the participant stopped, and the final score was calculated by subtracting the number of incorrect hops (incomplete clearance of the line) from the total number of correct hops (complete clearance over the line) [42].

Intervention

The experimental group performed an eight-week core stability exercise program based on the frequency, intensity, time, and type (FITT) principle, three days a week (each session lasting 45 minutes), alongside regular basketball training. The training focused on the abdominal, back, and hip muscles (Table 1), whereas the control group engaged in regular basketball training, emphasizing basketball-specific skills, such as shooting, passing, dribbling, defensive and offensive drills, and agility. Finally, the post-test phase was conducted after completing the core stability exercise protocol.

Data analysis

This study employed descriptive statistics to characterize the variables and utilized inferential statistics for data analysis. The normality of the data distribution was assessed using the Shapiro-Wilk test. If normally distributed, analysis of covariance (ANCOVA) was used; otherwise, Quade's test was utilized for non-parametric data. Statistical analysis was performed using SPSS software, version 27, with significance determined at the 95% confidence level and an alpha ≤0.05.

Results

Table 2 presents the demographic characteristics of participants across both groups. No significant differences were observed in the demographic data across the study groups.

Table 3 presents a difference between the core exercise and control groups in the DS (P=0.021), HS (P=0.006), ILL (P=0.001), SM (P=0.001), ASLR (P=0.001), TSPU (P=0.001), RS (P=0.001), total FMS score (P=0.001), single-leg hop test (P=0.001), and zigzag triple hop test (P=0.001). These results show that the core stability exercises significantly affected FMS.

Table 4 presents a significant difference between the core exercise and control groups in the dominant upper limb balance scores (P=0.001), non-dominant upper limb balance scores (P=0.001), the square hop test (P=0.001), and the Davies CKC test (P=0.001). These results show that the core stability exercises significantly affected balance and performance.

Table 1. Eight-week protocol of core stability exercises

Week	Days	Exercises	Sets	Repetitions (r) or Time in Seconds (s)	Rest in Seconds
1	Sunday Tuesday Thursday	Pelvic curl	3	20 s	20 s
		Chest lift	3	12 r	30 s
		Leg lift side	3	10 r	20 s
		Spine twist supine	3	14 r	30 s
2	Sunday Tuesday Thursday	Pelvic curl	4	30 s	15 s
		Chest lift	4	15 r	20 s
		Leg lift side	4	10 r	15 s
		Spine twist supine	4	20 r	20 s
3	Sunday Tuesday Thursday	Shoulder bridge	3	15 s	15 s
		Chest lift with rotation	3	12 r	30 s
		Back extension prone	3	10 r	20 s
		Hundred	3	10 r	30 s
4	Sunday Tuesday Thursday	Shoulder bridge	4	20 s	10 s
		Chest lift with rotation	4	14 r	20 s
		Back extension prone	4	15 r	15 s
		Hundred	4	15 r	20 s
5	Sunday Tuesday Thursday	Double leg stretch	3	20 s	20 s
		Criss cross	3	20 r	30 s
		Leg pull front	3	10 r	20 s
		Side kick	2	10 r	20 s
6	Sunday Tuesday Thursday	Double leg stretch	4	30 s	15 s
		Criss cross	4	30 r	20 s
		Leg pull front	4	15 r	15 s
		Side kick	3	12 r	10 s
7	Sunday Tuesday Thursday	Teaser	3	20 s	20 s
		Hip twist with stretched arms	3	12 r	15 s
		Swimming	3	10 r	15 s
		Side bend	3	20 s	20 s
8	Sunday Tuesday Thursday	Teaser	4	30 s	15 s
		Hip twist with stretched arms	4	30 s	10 s
		Swimming	4	15 r	10 s
		Side bend	4	30 s	10 s

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Table 2. Demographic characteristics of participants

Variables	Mean±SD		P
	Core Exercises	Control Group	
Age (y)	21.70±3.27	20.11±1.86	0.144
Weight (kg)	88.76±8.25	87.64±8.48	0.700
Height (cm)	188.23±9.88	190.17±5.46	0.484
BMI (kg/m^2)	22.47±0.71	22.29±0.68	0.392
History of sports activity (y)	6.05±1.08	5.70±0.91	0.413
Weekly activity level (h)	6.17±1.13	6.29±1.10	0.734
Dominant upper limb length (cm)	93.85±4.82	95.38±3.52	0.299

BMI: Body mass index.

PHYSICAL TREATMENTS

Table 3. Quade's test results

Variables	Stage	Mean±SD		F	Mean Square	P*
		Core Exercises	Control Group			
Deep squat	Pre-test	2.17±0.39	1.82±0.80	5.850	190.934	0.021
	Post-test	2.58±0.50	1.88±0.78			
Hurdle step	Pre-test	2±0.70	1.88±0.48	8.604	400.309	0.006
	Post-test	2.47±0.51	1.94±0.55			
In-line lunge	Pre-test	1.94±0.82	2±0.50	17.201	788.450	0.001
	Post-test	2.52±0.51	1.88±0.48			
Shoulder mobility	Pre-test	2.05±1.08	2.29±0.77	14.073	700.216	0.001
	Post-test	2.64±0.49	2.05±0.55			
Active straight leg raise	Pre-test	1.88±0.78	2.29±0.46	13.098	609.503	0.001
	Post-test	2.35±0.49	1.76±0.43			
Trunk stability push-up	Pre-test	1.94±1.14	1.88±0.60	27.671	1223.723	0.001
	Post-test	2.70±0.46	1.76±0.56			
Rotary stability	Pre-test	1.88±0.60	1.94±0.55	21.749	937.868	0.001
	Post-test	2.47±0.51	1.70±0.58			
Total FMS score	Pre-test	13.88±2.97	14.11±1.72	86.360	2246.153	0.001
	Post-test	17.76±1.09	14.41±1.22			
Single-leg hop	Pre-test	176.29±14.81	174.76±13.44	30.661	247.872	0.001
	Post-test	185.29±14.99	174.58±13.85			
Zigzag triple hop test	Pre-test	466.64±70.85	463.70±31.09	17.011	226.383	0.001
	Post-test	517.05±137.56	464.76±31.46			

FMS: Functional movement screen.

*a significant change from pretest to post-test.

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Table 4. ANCOVA test results

Variables	Stage	Mean±SD		F	Eta Squared	P*
		Core Exercises	Control Group			
Dominant upper limb balance scores	Pre-test	99.83±13.10	98.78±6.08	71.632	0.698	0.001
	Post-test	108.19±11.54	99.10±6.01			
Non-dominant upper limb balance scores	Pre-test	93.34±5.76	92.59±6.72	268.858	0.897	0.001
	Post-test	100.53±5.10	92.90±6.64			
Square hop test	Pre-test	39.70±9.25	40.88±8.76	96.865	0.758	0.001
	Post-test	45.64±9.51	41.05±9.12			
Davies CKC test	Pre-test	30.88±6.47	32.82±5.31	90.444	0.745	0.001
	Post-test	39.41±5.78	33.11±5.25			

*a significant change from pretest to post-test.

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Discussion

Although core stability exercises are commonly used in rehabilitation and sports, there is limited research on their effects on FMS scores, balance, and performance in elite athletes. To our knowledge, this is the first study to investigate the effects of core stability exercises on these variables in elite basketball players. The core plays a crucial role in stabilizing the torso, which is essential for effectively generating, controlling, and transferring forces to both the upper- and lower-limb during functional movements [43]. It is believed that optimal core stability enhances movement efficiency and contributes to improved athletic performance [17].

The results of this study regarding the effect of core stability exercises on the FMS test are consistent with previous research. Hessam et al. (2023) examined the effect of McGill's core stability exercises on movement patterns, shooting accuracy, and performance in 40 male basketball players, finding them in improving FMS scores [23]. Kurt et al. (2023) reported that swimmers engaging in core stability exercises demonstrated improved performance and higher FMS test scores [44]. Furthermore, Majewska et al. (2022) showed that core stability exercises could increase the overall FMS score in tennis players from 14.44 to 16.91 [45]. Additionally, Rahimi et al. (2023, 2021) support the positive effect of core stability exercises on FMS scores of elite karate and wrestling athletes aged 9-12 years [46, 47]. Daneshjoo et al. (2020) found that core stability exercises significantly improve static and dynamic balance and increase adolescent football players' FMS scores [48]. Lago-Fuentes et al. (2018) similarly reported significant improvements in FMS and agility in futsal players after core stability interventions [24]. These findings collectively indicate that core stability exercises positively impact athletes' movement patterns across various sports disciplines. Specifically, core region instability has been linked to poor running technique and ineffective force application [49]. In various studies, the correlation between weak core muscles and an increased occurrence of upper and lower limb injuries in athletes has been reported. In this regard, Šiupšinskas et al. (2019) found that dysfunctional movement patterns and weak biomechanics during landing in pre-season screening tests correlate with an increased risk of lower limb injuries in female basketball players during the season [50]. Core stability exercises are widely used in rehabilitation programs and are essential for optimal performance in most activities [15]. Exercises that improve both strength and coordination of the core muscles may affect participants' ability to activate muscles in a coordinated manner and lead to increased force production [51]. Changes in coordination, increased force production, or both, may improve movement control in sports. Sedaghati et al. (2018) reported a positive correlation between trunk flexor endurance, balance, and FMS scores in basketball players, indicating that greater muscular endurance is associated with better FMS performance and higher balance scores [52]. These exercises indirectly improved kinetic chain alignment, acceleration, and balance, ultimately contributing to enhanced athletic performance. Through co-contraction of abdominal muscles and lumbar stabilizers, core stability exercises help prevent lateral torso displacement during the FMS test. This provides the necessary stability for lower limb movement across three planes of motion, thereby enhancing performance [53].

Regarding upper and lower limb performance, our findings align with previous research. Luo et al. (2023) reported that incorporating core training, especially on unstable surfaces, and integrating static and dynamic core exercises enhanced athletic performance and skill execution in basketball players [54]. Li (2022) found improvements in fast dribbling and shooting accuracy among basketball players following a six-week core stability exercise program [55]. Furthermore, a study on collegiate athletes demonstrated that core stability training enhanced the functional throwing performance index [56]. In overhead and throwing sports, the force and energy generated by the body are ultimately transferred to the ball. The execution of such skills involves a coordinated sequence of movements, where each component has the potential to influence the entire kinetic chain. For effective execution of throwing skills and efficient energy transfer along the kinetic chain, all body segments and joints must possess adequate stability, strength, endurance, mobility, and neuromuscular control [57]. The core region is particularly critical, acting as a biomechanical bridge between the upper and lower limbs. Disruptions in force generation within one segment can increase mechanical load on adjacent segments, potentially leading to injury in structurally weaker distal joints and segments [57]. Concerning the performance of the lower limb, Saki et al. (2021) reported that after an eight-week core program, single-leg hop and triple hop were improved [58]. Ebrahimi et al. (2024) indicated that the performance of taekwondo practitioners increased after six weeks of core stability training [59]. Furthermore, an eight-week core training program for 16-18-year-old basketball players demonstrated positive effects on vertical jump performance [60]. Enhancing core strength improves the stability of the pelvic girdle, spine, and hip joints, providing a stable base of support for lower limb movements. This, in turn, facilitates more coordinated motion and better postural control during rapid directional changes [61]. Jumping performance is influenced by trunk and pelvic control, as these regions contribute significantly to the stability and force generation required by the lower limb and hip extensor muscles during jumping tasks [24].

Regarding balance, our findings are consistent with previous studies. Javdaneh et al. (2020) demonstrated that core exercises affect dynamic balance and postural sway in basketball athletes [62]. Gong et al. (2024) conducted a study comparing the effects of a ten-week core stability program with traditional strength training on balance performance in adolescent male basketball players. Their findings indicated that core stability exercises led to notable enhancements in dynamic balance and agility across various movement planes [63]. In addition, Liu (2022) found that basketball players showed better coordination and balance after completing a core training program [64]. Dogan et al. (2021) also reported that after eight weeks of a core strength training program, basketball players had better balance and general strength [22]. Core stability enhances the body's ability to maintain balance during dynamic movements and contributes to appropriate force production, thereby aiding in injury prevention [65]. The primary goal of core training is to develop the physical capacity to retain a neutral spinal alignment during daily functional activities. This is achieved by improving the endurance and coordination of spinal stabilizer muscles, including the obliques, transversus abdominis, multifidus, and erector spinae [66].

Furthermore, the core region serves as the location of the body's center of gravity and the origin point of all bodily movements. Thus, strengthening the musculature of this area through core stability training enhances neuromuscular efficiency and promotes optimal joint motion of the lumbar spine, pelvis, and hips throughout the functional kinetic chain. It also supports appropriate acceleration and deceleration, muscular balance, proximal stability, and functional strength [67]. High-intensity, multidirectional motions are common among elite basketball players, necessitating fine neuromuscular control, dynamic balance, and ideal force transfer along the kinetic chain. Therefore, incorporating core stability exercises into training regimens can enhance the balance, FMS scores, and overall athletic performance of elite basketball players. Specifically, we emphasize that incorporating structured core stability training into regular practice routines is a time-efficient and targeted strategy to improve key performance-related outcomes, such as movement quality, dynamic balance, and functional power. These improvements are particularly relevant for enhancing on-court performance and may support injury prevention strategies in elite basketball athletes. This study has several limitations: the absence of follow-up to assess the durability of exercise effects on the measured variables; a small sample size; and the lack of muscle length evaluation, which may influence performance outcomes in certain tests. Future research is recommended to include female, amateur, and semi-professional basketball players, and to quantify changes in core muscle activation patterns during basketball-specific skills before and after exercise interventions.

Conclusion

The current study's results showed that after eight weeks of core stability exercises, elite basketball players experienced significant improvements in FMS scores, balance, and performance. These findings highlight the positive effect of core-focused exercises on enhancing movement efficiency and athletic performance, with important implications for reducing injury risk in elite athletes.

Ethical Considerations

Compliance with ethical guidelines

All research procedures were conducted in accordance with the ethical guidelines of the Physical Education and Sports Science Research Institute (Code: SSRI.REC-2310-2462). Before the commencement of the study and measurements, participants provided informed consent by completing a consent form.

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Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interpretation of results, and drafting of the manuscript. All authors consented to the final version of the manuscript prior to submission.

Conflict of interest

The authors declared no conflicts of interest.

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