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THE EFFECTS OF DIFFERENT EXERCISE PROGRAMMES ON INJURY RISK AND EXPLOSIVE POWER IN ADOLESCENT BASKETBALL PLAYERS: A RANDOMISED CONTROLLED TRIAL

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ABSTRACT

This study analysed the effects of different exercise programmes on basketball players. Participants were randomly assigned to core stability (CSG), neuromuscular exercise (NEG) or control group (CG). Over 8 weeks, CSG performed core exercises, NEG neuromuscular exercises, and CG routine warm-ups. Assessments included the Functional Movement Screen (FMS), vertical jump (VJ), horizontal jump (HJ) and sprint tests. Post-test results showed improvements in deep squat, in-line lunge, shoulder mobility push-up, rotational mobility and FMS-total scores for CSG and NEG compared with CG ($p<0.05$). Post-test rotary stability scores were higher in CSG compared with NEG and CG, while active straight leg raise and trunk stability push-up scores were greater in CSG than CG ($p<0.05$). Both CSG and NEG showed improvements in VJ and sprint scores compared with CG ($p<0.05$). CSG improved in deep squat, trunk stability push-up, rotary stability and FMS-total scores compared with NEG and CG, while NEG had greater increases in VJ and sprint scores than CSG and CG ($p<0.05$). While core stability and neuromuscular exercises enhanced explosive power and FMS scores, suggesting a potential reduction in injury risk, the study did not directly measure injury incidence. Therefore, these exercises should be considered part of a broader injury prevention strategy.

Keywords: Basketball; Exercise; Power; Prevention.

INTRODUCTION

Basketball is a sport that demands high levels of physical skill and conditioning. In addition to aerobic and anaerobic performance capacities, it involves high-intensity movements such as jumps, sprints, rapid directional changes and sudden stops, which are fundamental to the game. These inherent movements require not only endurance but also muscle strength, flexibility, agility, dynamic balance and sport-specific skills (Ahmad Bhat *et al*., 2019; Meszler & Váczi, 2019; Šiupšinskas *et al*., 2019; Mendhe & Borkar, 2021). Therefore, enhancing these biomotor abilities in basketball players can improve performance and reduce the risk of injury (An & Lee, 2021). There exist various programmes such as those including core stability and neuromuscular exercises aimed at improving the biomotor skills of basketball players, such as strength, speed, agility, flexibility and balance, to raise their performance and lower their risk of injury (Harries *et al*., 2015; Zemková & Zapletalová, 2022). In particular, integrating core stability and neuromuscular exercises into explosive power training programmes can play a role in increasing performance and minimising risk factors of injury, as they correct muscle imbalances and body stability while developing functional movement patterns (McGill, 2010; Myer *et al*., 2014).

Insufficient neuromuscular control of core muscles can negatively affect the dynamic stability of the lower extremities during high-speed athletic manoeuvres. Muscle capacity and neuromuscular control are the key components of core stability (Zazulak *et al*., 2007; Silfies *et al*., 2015). Deficiencies in core muscles can increase injury risk and lead to a decrease in performance. Therefore, it is recommended to include core training in warm-up or main training programmes (Sannicandro & Cofano, 2015; Silfies *et al*., 2015; Bahiraei *et al*., 2019).

In the literature, it has been stated that multicomponent neuromuscular exercises containing plyometrics, strength and dynamic warm-up exercises decrease injuries (Davis *et al*., 2021). Neuromuscular exercises that can be used both in warm-up and training programmes include the components of agility, strength and balance (McCarty *et al*., 2008; Soligard *et al*., 2009; Emery & Pasanen, 2019; Caldemeyer *et al*., 2020). Recent studies conducted with women show that neuromuscular exercises reduce injury risk and improve various biomotor skills, thereby enhancing performance (Caldemeyer *et al*., 2020; Mendez-Rebolledo *et al*., 2021).

To determine deficiencies in neuromuscular status related to increased injury risk and examine the relationships of these to performance, movement-competence-based tests have been developed. These tests aim to identify existing asymmetries, imbalances, and movement capacities in athletes by analysing movement patterns. One of these tests is the **Functional Movement Screen (FMS)** (Aktug *et al.,* 2019; Kocak & Unver, 2019). While the FMS is an assessment method that has been developed to screen for movement inefficiencies, it has an important role in the indirect measurement of injury risk by highlighting functional limitations (Cook *et al*., 2006; 2014). Stability and mobility deficiencies caused by mechanical imbalances that pave the way for injury in athletes can be identified using the FMS (Chorba *et al*., 2010; Madruga-Parera *et al*., 2019). Studies have shown that when the deficiencies identified using the FMS are combined with neuromuscular exercises and strength training programmes, they can reduce injury risk and increase performance by improving motor control and balance skills, especially in young and female athletes (Myer *et al.,* 2005; Nesser *et al*., 2008).

In female basketball players particularly, knee and ankle injuries are more common (Cook *et al.,* 2006). As emphasised by Cook *et al*., the FMS can help indirectly identify the risk of injury and potential risk factors associated with performance by evaluating the functional movement skills of the athlete. In this context, mitigating injury risk factors and increasing performance is important, especially in sports like basketball that require high levels of explosive power. It is also important to improve explosive power for basketball players to be successful in activities such as jumping, passing, and shooting (Armstrong & Greig, 2018). In addition to this, the number of studies in the literature on the FMS in relation to injury risk and its effects on explosive power in adolescent female basketball players is insufficient. For this reason, in this study, it was aimed to examine the effects of different exercise programmes on injury risk, sprint performance, and vertical and horizontal jumping skills, which can be indirectly associated with the FMS, in adolescent female basketball players.

MATERIALS AND METHODS

This study was conducted with the participation of female basketball players within the age range of 12–18 years in Sinop, Turkey. Considering that the effect size of the number of participants in the study would be large, the minimum sample size required for the study was determined as 51 individuals by G*Power 3.1.9.2 software, at f=0.40, α=0.05, and 80% (1–β=0.20) power. Being a female basketball player with a minimum of 2-year license who trained at least 4 days a week were determined as the inclusion criteria, while having a history of any lower extremity injury or surgery experienced in the last 6 months and missing at least two consecutive basketball training sessions were determined as the exclusion criteria.

Before and after the 8-week exercise programme performed by the participants, the FMS was administered to evaluate injury risk and functionality, and the vertical jump (VJ), horizontal jump (HJ), and 30-metre (m) sprint tests were applied to evaluate the explosive power of the lower extremities. All tests before and after the exercise programmes were applied to each participant on two different days in the same week, where the FMS was applied first, and the explosive power tests were applied on the other day. The participants were given a 3-minute (min) rest interval between the explosive power tests. All assessments were performed by the same physiotherapist. Considering the circadian rhythm, all assessments were performed at similar times (16:00–18:00) for all participants.

Before the administration of the pretests, using the simple randomisation method the participants were divided into three different groups: the core stability group (CSG), the neuromuscular exercise group (NEG) and the control group (CG). The participants in CSG were assigned core stability exercises 3 days a week for 8 weeks in addition to their routine training programmes, and the participants in NEG were assigned multicomponent neuromuscular exercises performed with body weight, which included speed running exercises containing dribbling at low speed, active stretching exercises, general strength, balance, jump and agility, 3 days a week for 8 weeks. The participants in CG were asked to continue their routine training programmes that included dynamic stretching exercises.

Before the study was conducted, written and verbal information about the trial was provided to the participants. Written informed consent was obtained from all participants and their families.

The CONSORT 2010 flow diagram of the study is presented in Figure 1.

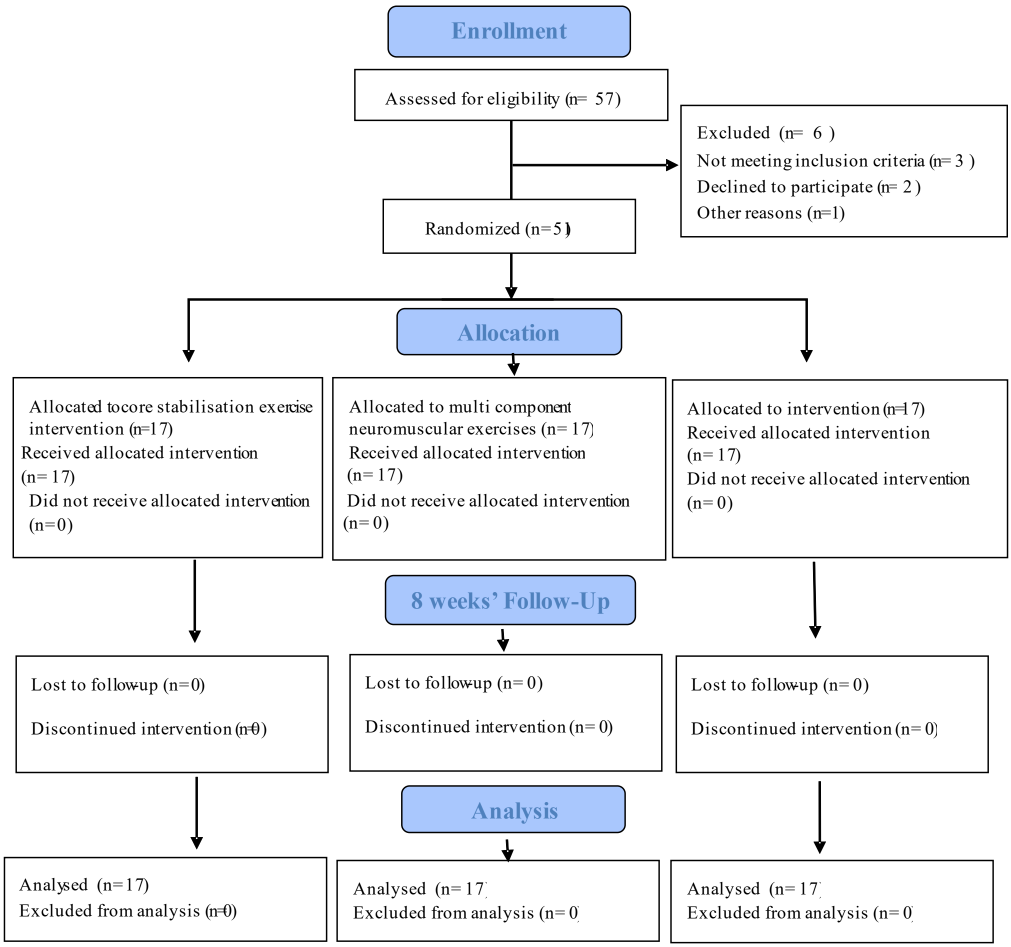

Figure 1. **CONSORT flow diagram of study participants**

Ethical considerations

This study was carried out respecting the ethical principles outlined in the Declaration of Helsinki. The study was approved by the Health Ethics Sub-Committee of the Scientific Research and Publications Committee of Eastern Mediterranean University (decision no: ETK00-2021-0086). The clinical trials number of the study is NCT05184543.

Evaluations and tests

1 – Sociodemographic information

Information was collected from the participants regarding their age, dominant side (leg), background and exercise habits. Their weights were measured on a digital scale and recorded in kilograms (kg), their heights were measured with stadiometer and recorded in metres (m), and their BMI values were calculated by using the formula of weight (kg)/height-squared (m) and recorded in kg/m^2.

2 – Injury risk and functional movement

The FMS was used in the study to determine injury risk and functional movement. Seven subtests scored on a 3-point Likert-type scale between 0 and 3, which included deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability, were applied to the participants (Pourheydari *et al*., 2018; Reina *et al*., 2018).

3 – Explosive power

a. VJ: The VJ distances of the participants were measured with the help of the Microgate OptoJump® (Microgate, Bolzano, Italy) device. Before the test, the participants were given a chance of one trial, and following a minute of rest, the test jump was done two times. The best score was recorded as the test result (Davis *et al*., 2000).

b. Horizontal jump: This parameter was measured with the standing long jump test. The participants were allowed to perform one trial jump, and following one minute of rest, the test was repeated two times. The best score was recorded as the test result (Bonato *et al*., 2018).

c. 30 m sprint: To evaluate the 30-m sprint times of the participants, the Witty wireless training timer (Microgate, Bolzano-Italy) was used. The participants were allowed one trial, and after a 1-minute rest, the test was repeated two times. The best score was recorded as the test result (Domčeková *et al*., 2023)

Training programmes

1 – Core stability group

The participants in CSG were assigned 20-minute core stability exercises 3 days a week for 8 weeks in addition to the warm-up programmes of their routine basketball training regimens. In the first 4 weeks, they performed core stability exercises at constant intensity on a stable surface, while they performed these exercises in the second set of 4 weeks at the same intensity on unstable ground.

The exercises assigned to CSG included plank (2 × 10 repetitions × 10 s), side plank (2 × 8 repetitions × 10 s), side plank with up and down hip movements (2 × 8 repetitions), and mountain climb (4 × 6 repetitions) (Sannicandro & Cofano, 2015). During the plank exercises, each participant performed 2 sets of movements with 10 repetitions in each set and 10 s of isometric exercise in each repetition. Afterward, each participant performed 2 sets of movements with 8 repetitions in each set and 10 s of isometric size plank exercise in each repetition. During the exercises, 10-s resting breaks were given between the repetitions and sets. The participants completed the session by performing the side plank with up and down hip movements exercise in 2 sets of 8 repetitions and the mountain climb exercise in 4 sets of 6 repetitions. In this process, 30-s resting breaks were given between repetitions. The reason for planning the core stability exercises with the inclusion of plank exercises and their variations was the reports in the literature that these exercises and variations provide more effective core training in that they increase the stability of the spine by working both superficial and deeper muscles (Cook *et al.,* 2006; Escamilla *et al.,* 2016).

2 – Neuromuscular exercise group

The participants in NEG were assigned 8 weeks of multicomponent neuromuscular exercises performed with body weight, including running at low speed, active stretching, general strength, balance, jumping, agility and sprint exercises for 20 min, and their warm-up programmes of routine basketball training. This programme was chosen because it did not require any equipment, and it could be easily integrated into traditional warm-up routines.

The 20-min exercise programme applied in NEG was divided into five different parts. At the beginning of the programme, exercises involving running with a ball at low speed were performed. The running track was set as covering an area of four basketball courts. In the second part, active stretching exercises were performed. The exercises were focused on general strength in the third part, and plyometric, balance and jumping exercises were assigned in the fourth part. In the final part, exercises were completed with sudden direction changes and a sprint programme with basketball movements (Cook *et al*., 2006; Bonato *et al*., 2018) (Table 1).

3 – Control group

The participants in CG continued their routine basketball training and warm-up programmes for 8 weeks. During the routinely performed warm-up programmes, the participants performed medium-intensity active stretching exercises addressing the wrist, biceps, triceps, all shoulder muscles, hip flexors, quadriceps, hamstrings, gastrocnemius and spinal muscles for 20 min.

Table 1. **MULTICOMPONENT EXERCISES PERFORMED BY THE PARTICIPANTS IN THE NEUROMUSCULAR EXERCISE GROUP**

Section	Exercise duration (min)	Rest duration (min)	Exercises	Number of reps and intensity
Running with ball at low speed	3	1	Low-speed dribbling with a basketball, half-court running	Continuous 3 min Low intensity
Active stretching	3	1	Hip flexors, quadriceps, hamstrings, and gastrocnemius stretching	2 sets of each stretch, hold for 15 seconds Low intensity
General strength	3	1	Body weight squat, lunge, plank variations	2 sets of each exercise, 10 reps Medium intensity
Plyometric, balance, and jump	3	1	Light jumps, balance board, double foot jumps	2 sets of each exercise, 10 reps Medium intensity
Sudden direction changes and sprint	3	1	Sudden changes of direction, short-distance sprinting, quick movements with the ball	2 sets of each exercise, 5 reps High intensity

min=exercise and rest times in minutes

Statistical analysis

In the statistical analysis of the data obtained in the study, the Statistical Package for the Social Sciences (SPSS) 26.0 software was used. The normality of the distribution of the data was checked with the Shapiro–Wilk test, and it was found that the data did not show a normal distribution. Accordingly, non-parametric tests were employed in the study.

Descriptive statistics were calculated for the age and anthropometric measurement data of the participants. The Kruskal–Wallis test was conducted for the intergroup comparisons of these values. The Kruskal-Wallis H test was also used to compare the deep squat, hurdle step, in-line lunge, shoulder mobility push-up, active straight leg raise, trunk stability push-up, rotary stability, and FMS total, jump, and sprint scores, vertical and horizontal jump results, and 30-m sprint test results of the participants among the groups. Intragroup comparisons were made using the Wilcoxon test.

In the comparisons of the changes in the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, rotary stability, and FMS total, jump, and sprint score outcomes of the participants, ANCOVA was performed. The pretest results of the participants were used as covariates in the ANCOVA. The purpose of using the pretest results as covariates in ANCOVA with a pretest–post-test design is to reduce the error variance and eliminate systematic bias.

RESULTS

The study was completed with 51 adolescent female basketball players. Descriptive statistics regarding the ages and anthropomorphic measurements of the participants distributed according to their groups, as well as the results of the intergroup comparisons, are presented in Table 2. Accordingly, it was determined that there was no statistically significant difference among the groups in terms of their age, weight, height or BMI values (p>0.05) (Table 2).

***Table 2.* AGE AND ANTHROPOMETRIC MEASUREMENTS OF THE ATHLETES ACCORDING TO THEIR GROUPS**

	Group	n	$\bar{x}$	s	M	MR	χ^2	p
Age	Core stability	17	14.53	1.97	13.00	27.74		
	Neuromuscular	17	14.18	1.94	13.00	25.26	0.414	0.813
	Control	17	14.06	1.64	13.00	25.00		
Weight (kg)	Core stability	17	55.12	8.28	55.00	27.06		
	Neuromuscular	17	53.35	7.80	52.00	24.21	0.377	0.828
	Control	17	54.35	8.09	52.00	26.74		
Height (cm)	Core stability	17	163.18	6.78	163.00	27.68		
	Neuromuscular	17	163.24	5.98	164.00	27.97	1.546	0.462
	Control	17	160.76	5.67	160.00	22.35		
BMI (kg/m^2)	Core stability	17	20.60	1.77	20.20	27.21		
	Neuromuscular	17	19.99	2.48	19.72	22.03	1.913	0.384
	Control	17	21.02	2.93	20.70	28.76		

BMI=body mass index n=frequency $\bar{x}$=mean s=standard deviation; M=median p=comparison between groups χ^2=chi-squared MR=mean rank; ***p*<0.05**

There were no statistically significant differences among the groups in term of any of the FMS parameters (p>0.05). In CSG and NEG, there was a significant increase in the post-test deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, rotary stability and FMS total score results of the participants (p<0.05). No significant change was determined in CG (p>0.05). The post-test deep squat, in-line lunge, shoulder mobility and FMS scores of CSG and NEG were found to be higher than the scores of CG. Additionally, the post-test rotary stability scores of the participants in CSG were found to be significantly higher compared with the scores of those in NEG and CG (p<0.05). There was a statistically significant difference among the degrees of change in the FMS scores of the groups from the pretest to the post-test (p<0.05) (Table 3).

Table 3. **INTERGROUP COMPARISONS OF FUNCTIONAL MOVEMENT SCREEN**

	Group	**Pretest**			**Post-test**				**F**	
		M	IQR	*p*1	M	IQR	*p*2	*p*3	*p*4	ES
Deep squat	Core stability	3	1	0.584	3	1	0.000*	0.014*	6.029	
	Neuromuscular	2	1		3	1		0.005*	0.005*	**0.467**
	Control	2	1		2	1		0.000		
Hurdle step	Core stability	2	1	0.777	3	0.5	0.146	0.008*	3.253	
	Neuromuscular	3	0.5		3	0		0.002*	0.047*	**0.128**
	Control	3	1		3	1		0.083		
In-line lunge	Core stability	3	1	0.058	3	1	0.009*	0.003*	7.394	
	Neuromuscular	3	1		3	0.5		0.025*	0.002*	**0.284**
	Control	2	1.5		2	1.5		1.000		
Shoulder mobility	Core stability	2	0.5	0.259	2	0.5	0.017*	0.157	1.556	
	Neuromuscular	2	0.5		2	1		0.083	0.222	**0.153**
	Control	2	0		2	0		1.000		
Active straight leg raise	Core stability	2	1.5	0.613	3	1	0.002*	0.004*	2.741	
	Neuromuscular	3	1		2	1		0.008*	0.075	**0.261**
	Control	2	0		2	0		0.083		
Trunk stability push up	Core stability	2	1	0.616	3	1	0.000*	0.000*	24.800	
	Neuromuscular	3	1		2	0		0.003*	0.0000*	**0.589**
	Control	2	0.5		2	0.5		1.000		
Rotational stability	Core stability	2	1	0.100	2	1	0.000*	0.000*	22.277	
	Neuromuscular	2	1		2	0		0.0014*	0.000*	**0.510**
	Control	2	0		2	0		0.157		
FMS total	Core stability	14	2.5	0.955	19	1.5	0.000*	0.000*	91.462	
	Neuromuscular	19	1.5		17	1		0.000*	0.000*	**0.827**
	Control	15	1		15	1		0.003*		

M=median IQR=interquartile range *p*1=Pretest comparison between groups *p*2=post-test comparison between groups *p*3=intragroup pretest-posttest comparison *p*4 = ANCOVA comparison of post-test values adjusted for pretest scores F = ANCOVA ES=effect size. ***p<0.05***

It was determined that the effect sizes in the differences seen in hurdle step and shoulder mobility scores were small (η^2<0.25), those in seen in deep squat, in-line lunge, and active straight leg raise scores were medium (0.25<η^2<0.5), and those seen in trunk stability push-up, rotary stability and FMS total scores were large (η^2>0.5).

The jump and sprint scores of the participants are presented in Table 4.

Table 4. **INTERGROUP COMPARISONS OF EXPLOSIVE POWER VALUES**

	Group	Pretest			Post-test				F	
		$\bar{x}$	s	p_1	$\bar{x}$	s	p_2	p_3	p_4	ES
Vertical jump (cm)	Core stability	24.64	2.80	0.830	26.67	2.70	0.030*	0.000*	41.996 0.000*	**0.649**
	Neuromuscular	24.57	3.95		27.45	3.85		0.000*		
	Control	24.66	2.82		24.62	2.76		0.342		
Horizontal jump	Core stability	174.00	13.85	0.649	175.18	14.19	0.006*	0.568	55.384 0.000*	**0.697**
	Neuromuscular	176.41	11.09		189.35	13.03		0.000*		
	Control	175.59	10.87		175.82	10.65		0.464		
30-m sprint	Core stability	5.44	0.25	0.776	5.24	0.25	0.000*	0.000*	30.882 0.000*	**0.587**
	Neuromuscular	5.45	0.15		5.15	0.14		0.000*		
	Control	5.45	0.14		5.43	0.15		0.190		

x̄=mean s=standard deviation *p*=pretest comparison between groups *p*2=post-test comparison between groups *p*3=intragroup pretest–post-test comparison *p*4=ANCOVA comparison of post-test values adjusted for pretest scores F=ANCOVA ES=effect size; *p<0.05

There was no significant difference in any of the measured values in the pretest (p>0.05). Statistically significant differences were determined among the groups in terms of their post-test VJ, HJ and 30-m sprint scores (p<0.05). The VJ scores of CSG and NEG were found to be higher compared with the scores of CG. The HJ scores of NEG were found to be higher than those of CSG and CG (p<0.05). The 30-m sprint times of CSG and NEG were shorter in seconds than those of CG. In CG, there was no significant difference between pretest and post-test explosive power scores (p>0.05). Statistically significant differences were found among the groups in terms of the degrees of change in VJ, HJ and 30-m sprint scores from the pretest to the post-test (p<0.05). The degrees of increase in the VJ and HJ (m) scores of NEG and the degree of decrease in their 30-m sprint (sec) scores were significantly greater compared with CSG (p<0.05) (Table 4).

The effect size in the differences seen in VJ, HJ, and 30 m sprint results was determined to be large (η^2>0.5).

DISCUSSION

The results of this study showed that both core stability exercises and multicomponent neuromuscular exercises performed with body weight in the warm-up programmes of adolescent female basketball players improved their FMS scores and jump and sprint parameters. It was determined that the FMS rotary stability and in-line lunge scores of the CSG improved to a higher extent compared to the NEG and the CG, and the degrees of increase in theVJ, HJ and 30-m sprint scores of NEG were greater in comparison with those of CSG and CG. These results were similar to the results of previous studies showing that core exercises are effective not only in reducing the risk of injury but also in increasing performance (Doğan, 2018; Bagherian *et al*., 2019).

Bagherian *et al*. (2019) reported that 8 weeks of core stability exercises performed by 12–14-year-old male basketball players significantly improved their FMS scores. Similarly, Dogan *et al*. (2018) showed that core exercises raised the FMS scores of university students, and this increase was associated with the improvement of movement patterns by the strengthening of core muscles. It is known that inadequate core stability affects the lower extremity and trunk biomechanics of athletes negatively, ultimately disrupting functional movement and increasing the risk of injury (Bahiraei *et al*., 2019; Sasaki *et al*., 2019). We believed that in our study, core stability exercises including plant, side plant and mountain climber exercises contributed to the more efficient usage of lower extremity muscles by increasing pelvic muscle strength and stability, and thus, they resulted in significant enhancements in explosive power and functional movement. These results were compatible with the report of Sannicandro *et al*. (2020), who showed that core stability exercises increased the sprint and jumping performance of prepubertal basketball players by improving their control of the trunk and pelvis. Studies carried out in recent years demonstrated that core stability training programs supported athletic performance and lowered the risk of injury (Dong *et al*., 2023; Weber *et al*., 2024). In contrast with our result, Sever *et al*. (2018) found that core exercises did not lead to a significant change in sprint and jumping performance in football players between the ages of 16 and 18 and argued that core training might not be sufficient in creating the necessary stimulation to improve power-related performance skills in football players.

In NEG, we observed significant improvements in deep squat, hurdle step, in-line lunge, active straight leg raise, trunk stability push-up, rotary stability, FMS total scores, jump test results and sprint test results. These results were in agreement with the results published by Mendez-Rebolledo *et al*. (2021), who demonstrated that a multicomponent neuromuscular exercise programme performed by 11–18-year-old female athletes raised their sprint and jumping performance levels and reduced their risk of tibial stress injury. This shows the potential of neuromuscular exercises to not only improve performance but also reduce injury risk by correcting sport-specific body biomechanics and increasing lower extremity strength. Similarly, Cook *et al*. (2006) stated that adding neuromuscular exercises to routine warm-up programmes increased the jumping performance of elite female basketball players and reduced their rates of lower extremity injury. These results supported the improvements we observed in the performance parameters of NEG in our study. Sugimoto *et al*. (2018) found that neuromuscular training programmes were effective in preventing anterior cruciate ligament (ACL) injuries in young female athletes, and this result was consistent with the results of NEG in our study. Moreover, in a similar vein to our study, Sanudo *et al*. (2019) reported that neuromuscular exercises could reduce injury risk in young athletes while also improving their performance.

Cook et al. (2006) emphasised that the FMS is not a tool directly predictive of injury, but it projects the risk of injury indirectly by identifying limitations and asymmetries in movement patterns. In this context, it is seen that the FMS supports the planning of interventions aiming to optimise performance and prevent injuries by detecting deficiencies in movement patterns (Butler *et al*., 2013; Shimoura *et al*., 2019). While Shimoura *et al.* (2019) stated that deep squat and hurdle step scores in the FSM could be associated with the risk of injury in basketball players, the results of NEG and CSG in our study suggested that improvements in these movement patterns could contribute indirectly to the prevention of injuries. Our results were consistent with the literature showing that core stability and neuromuscular training programs have the potential to support athletic performance and reduce the risk of injuries.

Although the FMS is not a direct prediction instrument for injury risk, it is accepted as an instrument that can indirectly estimate this risk by assessing limitations and asymmetries in the movement patterns of athletes. This is in line with the objective of our study, which involved the development of strategies to improve the quality of movement and prevent injuries. Our results were especially supported by studies showing that FMS testing in adolescent female athletes contributes to the planning of training programs by identifying movement asymmetries (Cook *et al*., 2014; Warren *et al*., 2015).

Limitations

Only female basketball players in the age range of 12–18 years were included in the study. Therefore, the results of the study are valid only for adolescent female athletes. The results do not cover male basketball players and female athletes in other age groups.

CONCLUSION

This study investigated the effects of various exercise programs on injury risk factors and athletic performance in adolescent female basketball players. According to the results, multicomponent neuromuscular exercises and core stability exercises included in basketball players' warm-up programmes proved important in preventing sports injuries indirectly, while improving functional movement and increasing sprint and jump performance in female basketball players.

The finding that core stability exercises led to greater degrees of increase in deep squat, trunk stability push-up, rotary stability and FMS score results compared with neuromuscular exercises performed with body weight and routine warm-up exercises involving stretching showed that including core stability exercises in the warm-up programmes of basketball players is important in terms of preventing injuries.

On the other hand, the analyses of the collected data revealed that neuromuscular exercises performed with body weight led to more significant improvements in VJ, HJ, and 30-m sprint scores in comparison to core stability exercises and routine warm-up exercises. This showed that multicomponent neuromuscular exercises performed with body weight also had the potential to increase explosive power in basketball players.

Consequently, this study offers valuable evidence of the role of neuromuscular exercises and core stability exercises in improving functional performance and indirectly preventing movement-related injury risk factors. Nevertheless, more studies are needed to confirm the relationship between these factors and injury risk.

IMPLICATIONS

As a contribution to the literature, including a combination of both types of exercises in warm-up programs is necessary for preventing injuries, improving functional movement, and increasing performance in adolescent female basketball players. We can also say that core stabilisation exercises are more effective in improving functional movements and preventing injuries, and multicomponent neuromuscular exercises are more effective in increasing explosive power. In future research, the effectiveness of warm-up exercises extending over a few seasons on injury risks and other performance parameters can be investigated. There is also a need for making detailed measurements such as electromyography (EMG) measurements.

Conflict of interest

The authors have declared no potential conflict of interest.

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