Research Paper

The Effect of the Neuromuscular, Strength, and Combined Training on Balance and Performance in Female Basketball Players

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ABSTRACT

Purpose: This investigation aimed to compare the effect of neuromuscular, strength, and combined training on dynamic balance and sports performance, including power, sprint, and agility in female basketball players.

Methods: In this semi-experimental study, 42 female professional basketball players (age: 19-25 years) were assigned to three groups of Neuromuscular (NM), Strength (ST), and Combined training (CM), and one control group. The Multivariate Analysis of the Variance (MANOVA) was used to compare between-groups data. Dynamic balance and performance measurements (vertical jump, agility, and sprint) of athletes were assessed before and after six weeks of intervention by Star Excursion Balance Test (SEBT), Sargent vertical jump device, Shuttle Run device, and sprint 27-meter test.

Results: Results of the MANOVA showed all between-group differences for dynamic balance, sprint, and agility were only significant between the control group and NM, ST, and CM groups ($P \leq 0.05$). In addition, the CM group was significantly different compared to the NM and ST groups ($P \leq 0.05$). Balance and high jump within-group differences showed a significant increase in the NM, ST, and CM groups in the high jump variable ($P \leq 0.05$). For sprint and agility, within-group results showed a significant decrease in the NM, ST, and CM groups ($P \leq 0.05$). Besides, the larger effect size was seen in the combined group for all variables.

Conclusion: It seems that neuromuscular, strength, and combined training is similarly effective in improving the balance and functional performance of female basketball athletes and there is not a significant difference between them.

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Highlights

- Neuromuscular and strength training can improve dynamic balance in female basketball athletes.
- Neuromuscular and strength training are effective to improve agility, sprint, and vertical jump abilities.
- Combined neuromuscular and strength training is more effective than each of them alone, especially in high jump ability.

Plain Language Summary

This investigation aimed to compare the influence of neuromuscular, strength and combined trainings on dynamic balance and sport performance : sprint, agility and power abilities in female basketball players. 42 female elite basketball players participated in experimental trial and were assessed before and after six weeks of intervention protocols to three intervention and one control groups. It seems that training interventions are effective in improving the balance and functional performance in female athletes but considering the bigger effectiveness of combined training it is suggested to use combined training to benefit more from a comprehensive training either in conditioning or injury preventive measures in athletes especially female basketball players.

1. Introduction

Considering the high prevalence of non-traumatic injuries of lower limbs in female athletes, the researchers need to identify effective solutions that are simple, easy, and comply with training programs that can be easily used by the athletes or coaches and do not have many costs. An important part of the sports injuries studies is related to how neuromuscular function and their deficit can have an impact on the risk of sports injuries in female athletes [1, 2]. For this reason, many researchers place great emphasis on the use of conventional neuromuscular training methods [2-4]. Suss et al. state that participating in a neuromuscular exercise program provides dynamic joint stability, muscle imbalances correction, and sound biomechanical functions, which not only reduces the risk of non-traumatic injuries but also can reduce the sex dependence differences in performance. Thus, these exercises are said to be more useful in women since they lead to fewer injuries and improve athletic performance [5].

According to Myer et al. and some other researchers, improving biomechanical and neuromuscular function by teaching correct biomechanical techniques in neuromuscular training programs reduces the risk of injury in young female athletes and improves their performance, which typically includes sprint, agility, power, and jumping abilities as well as dynamic joint stability and reduces the risk of lower limb injuries [4, 6-8]. Previous findings have also shown that strength training, especially core stability training improves proprioception, dynamic balance, balance reflexes, and performance, and corrects muscle imbalances [9-12]. In addition, it possibly reduces the risk of lower limb injuries [10]. It is suggested that resistance training can potentially reduce or prevent injury risks through regular training [10, 11]. However, some recent findings have shown no neuromuscular performance changes after concurrent strength and endurance training [13]. On the other hand, according to some researchers, it is better to use both neuromuscular and strength training together to prevent non-traumatic injuries of the lower limbs in female athletes [7, 10].

Despite assessing the effects of using different methods of neuromuscular, strength, and combined training on injuries risks or performance, fewer comparisons have been made and the privilege of any type of them over others is not very clear. Therefore, regarding the importance of preventive measures toward decreasing injury risk, assessing beneficial training is of crucial importance. Female basketball players have been recruited to be tested in this study. the specific nature of basketball playing affects dynamic balance, it seems that female basketball players have a lower dynamic balance level than volleyball or football players, and on the other hand, the prevalence of injury seems to be higher in female basketball players [1, 7, 14, 15]. Another feature of this study was a longer period allocated to these training against prior studies, which mostly trained athletes during their warm-up programs in a shorter time.

Therefore, this study intended to investigate the effect of neuromuscular, strength, and combined training programs on neuromuscular function (dynamic balance) and athletic performance (speed, agility, and power) in female basketball players.

2. Materials and Methods

Subjects

Inclusion criteria were the age range of 19 to 25 years with at least three years of playing experience as a member of super league teams and the first batch of Fars province. Exclusion criteria included existing pain, history of injuries or surgery in the lower limb during the six months [16], any joint hypermobility in the Beighton test (which may interfere with muscle function [17]), significant malalignment in the lower limb (due to possible changes in biomechanical characteristics [18]), and participating in any other training program simultaneously. All examinations were done under physical therapist surveillance.

This study was semi-experimental, which assessed and compared the effect of some training programs suggested by previous researchers on the prevention of lower limb injuries [11, 17-19] and dynamic balance and athletic performance in female athletes. This study was registered at the Iranian Registry of Clinical Trials with the IRCT number of IRCT20190723044314N1 and the ethics code of IR.SSRC.REC.1398.070 was obtained. The Subjects were recruited from professional female basketball players in Shiraz and 42 cases were selected with the available method of sampling who were placed in three training groups (neuromuscular training, n=11, strength training, n=11, and combined training, n=10) and one control (n=10) group.

Measurements

Participants then were tested in a pre-test session to measure the functional dynamic balance (by star excursion balance test), high jump, sprint, and agility scores, one week before the initial training session. Before measurements, the way of completing tests was explained first and a consent form was signed by all participants. Post-test was performed approximately six weeks after the pre-test on th control and experimental subjects (four days after the final training session).

The Y balance test

The Y-balance test was used to test the functional dynamic balance ability [12]. The test was done in the way that subjects stood on the dominant leg in the center of the grid. Subjects tried to reach the most distal part of another leg to the farthest point in the lines drawn on the ground in anterior, posteromedial, and posterolateral directions. After getting acquainted with the test, measurements started. Each direction was tried six times and the seventh trial was recorded. The recorded score for each direction was then normalized by dividing the scores by the lower lime length for each person and then multiplied to 100 (lower limb length was measured by recording the distance from the lower end of the anterior iliac spine to lateral malleolus in standing position). Finally, the average of three directions was selected as the final dynamic balance score for comparisons [12].

The vertical high jump test

To measure the power of the lower limb, a two-foot-stand and reach test was conducted. It has high validity (0.80) and reliability (0.93) coefficients [19], and the test was done so that all subjects were instructed to jump as high as possible, and then the highest point they could touch with their preferred hand was recorded. Three trials were completed and the highest one was considered for further analysis [19].

The sprint test

The 27-meter sprint test was used as a means to measure the speed ability of each athlete. The time that participants could run the certain path as fast as possible was recorded with an accuracy of 0.01 a second. The best time of three trials was recorded [7].

The agility test

The ability of agility was measured by a 20- yard Shuttle Run. Subjects run 5 yards to the right then 10 yards to the left and again 5 yards to the right to finish 20 yards. A 3-minute rest was given between each trial and was recorded [16]. The higher record in second was recorded as a score for agility for each athlete.

Training interventions

Three experimental groups received six weeks of training (neuromuscular, strength, and combined) (Table 1) [6, 7, 9, 20]: three sessions a week with 35 to 50 minutes of training period per session; 35 minutes in the first and second weeks, 40 minutes for the third and fourth weeks and 50 minutes for the fifth and sixth weeks. The FITT (Frequency, Intensity, Time, Type) principle was done by increasing the total time of training via increasing sets of exercises; one set for week one to two, two sets for week three to four, and three sets for week five to six. The control group received no training during the six weeks. All training sessions were done under the examiner's supervision. After six weeks, all measurements were repeated in the post-test session. The used training is shown in Table 1.

Statistical analysis

After collecting all data from pre- and post-test sessions, all data were analyzed by SPSS software v. 21. The subject's demographic characteristics (mean and standard deviation) are reported in Table 2.

The Multivariate analysis of Variance (MANOVA) was used to investigate the effect of group and time (pre-test and post-test) on variables after obtaining the conditions (homogeneity of variance was confirmed by Leven's and Box's tests). Tukey's post hoc test was used to examine the differences between groups and the paired t-test was used to examine the within-groups comparison. The Kolmogorov-Smirnov test was used to assess the normality of the data. The significance level was considered at 0.05 with a confidence level of 95%.

3. Results

In this research, 42 subjects participated and their demographic data, age, height, weight, and Body mass index (BMI) are shown in Table 2. No significant differences were seen in demographic data between groups (P>0.05).

Results of between- and within-group comparisons are shown in Tables 3 and 4 and Figures 1 and 2. Between-group differences showed a significant increase in the M,

Table 1. The six-week training protocol used by the neuromuscular, strength, and combined groups

Groups	Week	Type	Set * Repetition (Train/Rest) Ratio
Neuromuscular training (plyometric)	First and second	Athletic position Wall jumps (ankle bounces) Squat jumps (frog jumps) Broad jump and hold Tuck jump (with abdominal crunch) Bounding for Distance Two to one, Stick landing Single-leg hop and hold	2*5 (1/3)
	Third and forth	Crossover hop, hop, hop, stick (right to left) Passing the ball (two-leg stance) Passing the ball (one leg stance)	2*7 (1/2)
	Fifth and sixth	Bouncing the ball with eyes opened Bouncing the ball with eyes closed Pushing each other off balance	2*8 (1/1)
Strength training	First and second	Squat Single-leg squat Split Split with rotation Walking lunges RDL (Romanian Deadlift) Single leg deadlifts Side planks Hip bridges Nordic hamstring lowers	2*5 (1/3)
	Third and forth	Leg cradles -supine Crunches Reverse crunch	2*7 (1/2)
	Fifth and sixth	Single leg heel raises Resistive Running_	2*8 (1/1)
Combined training	First and second	Neuromuscular: exercise number 1-2-4-11-12 Strength: exercise number 1-2-3-4-5	2*5 (1/3)
	Third and forth	Neuromuscular: prior exercises plus exercise number 5-14 Strength: prior exercises plus exercise numbers 10-13	2*7 (1/2)
	Fifth and sixth	Neuromuscular: prior exercises plus exercise number 3-6-9-15 Strength: prior exercises plus exercise number 15	2*8 (1/1)

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Table 2. Demographic data in each training group

Demographic Variables	Mean±SD			
	NM	ST	CM	Co
Age (Y)	20.36± 1.96	20±1.33	21.81±1.94	20.7±1.94
Height (cm)	171.09±5.64	172.2±5.64	176±6.01	170±7.63
Weight (Kg)	62.63±2.9	62.81±3.9	66.4±5.03	62.5±6.98
BMI (Kg/m²)	21.43±1.35	21±0.73	21.44±1.38	21.58±1.21

NM: Neuromuscular Training; ST: Strength Training; CM: Combined Training; Co: Control.

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ST, and CM groups following training compared to the control group for all Y-test, sprint, agility, and high jump tests (P≤0.05). No significant differences were seen among the experimental groups (NM, ST, and CM) in the balance, sprint, and agility tests (P>0.05). Except for the high jump, the results showed that the CM group had significant differences in other tests than the NM and ST groups (P≤0.05).

Pre- and post-test comparisons showed a significant increase in balance, sprint, agility, and high jump tests in all three NM, ST, and CM experimental groups (P≤0.05). The control group showed no significant differences before and after training (P>0.05). Cohen's effect sizes are shown in Table 4. The CM training had the greatest effect size for balance, sprint, agility, and high jump tests, followed by the NM training group.

4. Discussion

In this study, the effect of neuromuscular, strength and combined training on dynamic balance and athletic performance in female athletes was investigated. Regarding no differences in functional test scores in dominant and non-dominant legs after the training interventions, it can be concluded that the training had the same effect on both sides, which is consistent with other studies [12, 21, 22].

Dynamic balance improved following neuromuscular, strength, and combined training in each group, but no significant differences were seen between groups. This result was expected to some extent, because balance training as a usual neuromuscular training program, was included in the training programs of two groups of subjects (neuromuscular and combined training group), and contained balance and perturbation exercises on the mattress and wobble boards. It was due to the importance of postural control in maintaining dynamic stability and reducing the incidence of possible injuries in the lower extremities.

Another effective training to improve balance ability was core stability training, which was also included for the neuromuscular and combined training groups. Increasing the neuromuscular control of the trunk through core stability training is shown to improve dynamic balance which can decrease the risk of injury in women [21].

Most of the training programs, which are designed to prevent ankle and knee injuries focus on improving postural control and core stability to reduce the destructive forces on joints and consequently reduce non-contact injuries [22-31], but the cumulative effect of neuromuscular and strength training was less assessed.

The results of the present study indicated that all training groups showed some speed improvements. In the

Table 3. Between-group comparisons in the NM, ST, CM, and control group

Between-group Comparisons	Y-test	Sprint	Agility	High Jump
Wilk's lambda	P=0.003, F=4.98	P=0.001, F=9.1	P=0.001, F=3.47	P=0.02, F=3.71
Tukey results	NM/Co (P=0.0001)	NM/Co (P=0.0001)	NM/Co (P=0.0001)	NM/ Co (P=0.0001) NM/CM (P=0.0001)
	ST/Co (P=0.0001)	ST/Co (P=0.0001)	ST/Co (P=0.0001)	ST/Co (P=0.0001) ST/CM (P=0.0001)
	CM/Co (P=0.0001)	CM/Co (P=0.0001)	CM/Co (P=0.0001)	CM/Co (P=0.0001)

NM: Neuromuscular Training; ST: Strength Training; CM: Combined Training; Co: Control.

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Table 4. Within-group comparisons (pre and post-test) in the NM, ST, CM and control groups

Within-group Comparisons	P	Mean±SD		Cohen, Effect Size
		Pretest	Posttest	
Y-test	NM(P=0.001)	118.24±6.1	123.6±7.3	0.56
	ST(P=0.001)	114.46±4.5	116.32±6.3	0.12
	CM(P=0.001)	115.07±5.5	121.84±8.1	0.84
	CO(P=0.172)	113.03±4.1	113.5±3.2	-
Sprint	NM(P=0.001)	6.06±1.3	5.51±0.9	1.19
	ST(P=0.001)	6.04±1.1	5.75±1.2	0.6
	CM(P=0.001)	6.41±0.8	5.96±0.9	1.21
	CO(P=0.524)	6.43±1.2	6.51±0.8	-
Agility	NM(P=0.001)	10.85±2.3	9.87±1.7	0.93
	ST(P=0.001)	10.74±1.7	10.1±2.2	0.71
	CM(P=0.001)	10.81±2.1	9.9±0.8	1.4
	CO(P=0.631)	10.7±0.7	10.8±0.9	-
High jump	NM(P=0.001)	29.0±1.9	30.5±1.2	0.6
	ST(P=0.001)	30.4±0.7	32.4±1.5	0.7
	CM(P=0.001)	30.6±2.1	34.0±1.3	0.9
	CO(P=0.435)	28.4±1.2	28.9±2.1	-

NM: Neuromuscular Training, ST: Strength Training, CM: Combined Training, Co: Control

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neuromuscular training group, after six weeks of training, the speed of sprint (27 meters) improved significantly. Similarly, plyometric training to prevent lower limb injuries in female soccer players showed an improvement in the speed of running. Non-contact injuries in female soccer players were also reduced by more than 19% [3]. The results of another study on tennis players showed the positive effect of plyometric training on speed and agility so that players became faster and more agile, receiving more balls and playing more effectively [32].

In the strength training group, there was also an increase in speed but with lower effectiveness. Fast resistance training (rope running, as in the present study) primarily promotes movement [7], which may be related to the reported speed improvement.

It should be noted that despite the effectiveness of all three exercise programs in improving sprint performance, combined exercises showed a greater impact; however, no differences were seen between groups. Some researchers have shown that running resistance training improves speed and plyometric, and strength training can have cumulative effects on the speed increase of running [7, 32]. Thus, it expresses a kind of better neuromuscular coordination that happened after neuromuscular or strength training together.

Concerning agility, following the exercises in the neuromuscular, strength, and combined training groups, the level of agility improved significantly; however, no differences were seen between groups.

The neuromuscular training program to prevent lower limb injuries in female athletes improved agility and reduced non-contact injuries in female athletes [28, 32, 33]. Agility is the ability to maintain or control the position of the body while changing direction rapidly during movements [33]. Plyometric training usually involves stopping, starting, and changing direction explosively, which are components that can help to increase agility [32]. Plyo-

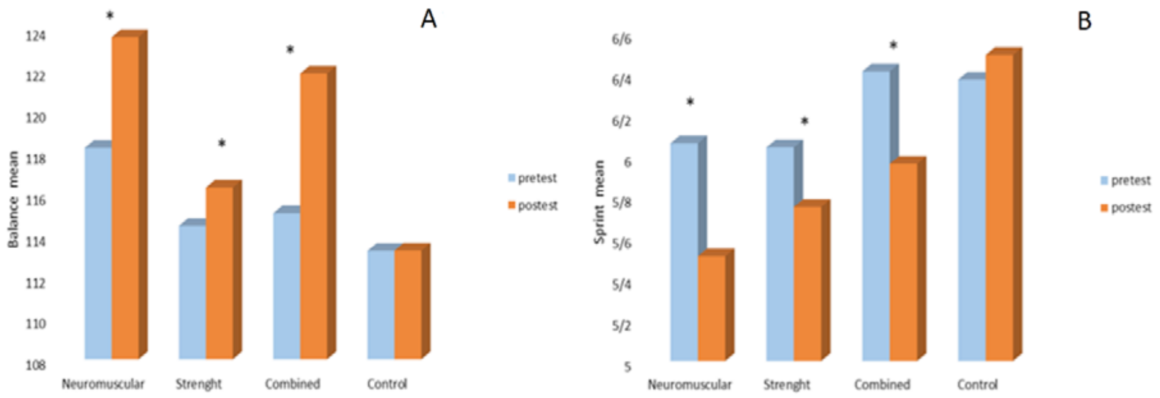

Figure 1. Mean differences in the balance (A) and the sprint (B) tests before and after training
*Within-group significant differences.

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metric training is thought to increase strength and efficiency, which may be one of the goals of agility training [28].

In the strength group, despite the smaller training effect, there was still an improvement in agility. Strength training is shown to improve motor programming by improving neuromuscular function and nerve adaptations in muscle spindles, Golgi tendon organs, or proprioceptive receptors. Strength training also seems to improve agility through increasing balance and controlling the body position during movements. Therefore, improvement in post-strength agility may be due to better motor unit recruitment or the development of neural adaptations, which can lead to better movement efficiency [29, 33, 34]. Therefore, the use of plyometric or strength training together seems to increase the strength and explosive power considerably to make athletes more agile.

The maximum vertical jump improved in all groups compared to the control group and the combined group showed significant differences from the neuromuscular and strength groups and it was more effective to improve the high jump. Similarly, other researchers have shown the effect of a plyometric exercise program on female athletes and an improvement has been reported in vertical jump ability, and this exercise program simultaneously improved dynamic knee stability or non-contact injuries [12, 14, 15]. However, the results of another study showed that four weeks of strength training in female volleyball players reduced vertical jump ability, which is against our results. Nonetheless, the neuromuscular changes in the early weeks of training decreased the performance but increased with the progress of the training period (eleven weeks of training) [10]. Panagoulise et al. indicated that neuromuscular strength training in adolescent athletes did not affect jumping performance, which may be attributed to different training types and duration or age of athletes [35]. Some other researchers found no improvement in jumping height after strength training [36, 37].

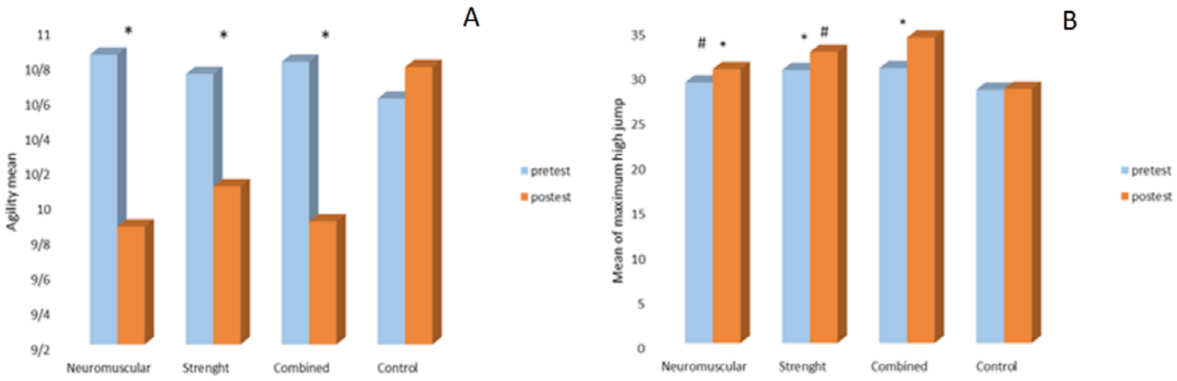

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Figure 2. Mean differences in agility (A, Second) and maximum high jump (B, Centimeter) tests, before and after training
*Within-group significant difference, #Significant difference with combined group.

The results showed more effectiveness for the neuromuscular training group compared to the strength group, which was seen in another study, in which lower extremity strength training caused a smaller increase in vertical jump performance in female athletes compared to the subjects who performed neuromuscular training [29]. These results are consistent with the present study. In contrast to another study, plyometric training (kind of neuromuscular training) was more effective in improving jumping performance compared to strength training [38].

In the combined group, more effectiveness was seen in improving vertical jump ability compared to other groups. It means that in the neuromuscular and strength training groups, the vertical jump did not improve as much as combined training, and combined training showed a greater advantage in improving vertical jump skills over neuromuscular and strength training alone. This indicates the cumulative effect of neuromuscular training combined with lower limb strength training on improving the vertical jump ability.

5. Conclusion

According to the results of this study, neuromuscular, strength, and combined training interventions were effective in improving athletic performances, including balance, agility, speed, and high jump of professional female basketball players compared to the control group. Although combined training was more effective in improving high jump ability compared to the strength and neuromuscular training alone, there was no significant difference between neuromuscular, strength, and combined training groups in other variables, such as agility, sprint, and Y-test.

Practical implications

Neuromuscular and strength training can improve dynamic balance in female basketball athletes.

Neuromuscular and strength training is effective in improving agility, sprint, and vertical jump abilities in female basketball athletes.

Combined neuromuscular and strength training is more effective than each of them alone in high jump ability in female basketball athletes.

Ethical Considerations

Compliance with ethical guidelines

This study was registered at the Iranian Registry of Clinical Trials with the IRCT number of IRCT20190723044314N1 also the Ethics Code was obtained (IR.SSRC.REC.1398.070).

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Authors' contributions

Conceptualization, Data collection Writing – review & editing, Funding acquisition and Resources, and Supervision: Negar Kooroshfard; Methodology, Data analysis, and Writing – original draft: Zahra Rahimi.

Conflict of interest

The authors declared no conflict of interest.

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