

# Effects of Neuromuscular Training on Motoric and Selected Basketball Skills in Pre-pubescent Basketball Players

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**Abstract** The aim of this study was to evaluate the effects of an 8 weeks neuromuscular training program (NTP) on motoric and selected basketball skills in pre-pubescent male basketball players. Twenty-four male basketball players were divided into two homogeneous groups according to pre-test results; an intervention group (n = 12, age =  $10.6 \pm 0.75$  years) and a control group (n = 12, age =  $10.8 \pm 0.68$  years). All players trained together as a team; however, the intervention group participated in an 8 weeks NTP two times per week, while the control group followed their regular basketball training system as guided by their coach. Motoric skills were assessed according to the results of an agility t-test, 20 meters sprint, and tests of back strength, vertical jump, standing long jump, sit and reach, and standing stork balance. Basketball skills were assessed according to shooting and dribbling tests. Significant differences were found only in vertical jump and flexibility in the control group ( $p < 0.05$ ), whereas significant differences were found in all motoric and shooting skills in the intervention group ( $p < 0.05$ ). In addition, according to pre-test and post-test analysis of variance (ANOVA) results of the motoric and basketball skill scores of the groups, significant differences revealed in favor of the intervention group in agility, back strength, long jump, flexibility, and balance ( $p < 0.05$ ). The present study demonstrated the significant effects of NTP, which focused on motoric and shooting skills in pre-pubescent male basketball players.

**Keywords** Athletic Performance, Basketball, Dribbling, Shooting, Training

## 1. Introduction

Basketball is a game of continuously changing tempo, requiring speed, acceleration, explosive movements such

as rebounding, passing, jump shooting, fast breaks and high speed play. The game also involves skills that must be applied dynamically, explosively and repeatedly [1]. So, basketball players must be strong, quick, and agile to effectively block, shoot, or pass the ball. They must be able to accelerate and decelerate quickly and with control, often while dribbling, shooting, or rebounding the ball. They also need to be able to repeat these actions many times with little rest between efforts throughout the game [2]. Thus, it is necessary that all of the basic motor skills such as strength, speed, endurance, reaction, mobility, skill and coordination are all together in basketball [3]. Regular practice of coordinated movements can lead to transformations in the skill level of movements related to well-developed motor features [4], which can be achieved by well-planned, scientific, sport-specific training methods.

Neuromuscular training aims to improve neuromuscular control, thus increasing functional joint stability [5], which may have a protective effect against injury. These training programs typically incorporate strengthening, stretching, plyometric, and balance components [6]. Neuromuscular trainings applied to male and female athletes in various branches is mostly focused on reducing lower limb injuries. Studies, comprising comprehensive warm-up neuromuscular programs [7-15] to improve strength, muscle activation, balance, dynamic stabilization, landing technique, core stability, agility, jumping etc., reported promising results, indicating that its intervention programs may reduce the incidence of knee and ankle injuries.

There is some indication that it is most advantageous to begin neuromuscular training during adolescence to train the body during a time of rapid musculoskeletal growth and decreased balance and coordination that occurs as a result of that growth [16,17]. A randomised controlled study [18] designed as a 6 months in-season neuromuscular programme for floorball players included sports-specific running technique, balance, jumping, and strengthening

exercises improved player's sideways jumping speed and balance. These findings supported the importance of whole body multi-station intervention training program for improving lower extremity control. Holm et al. [19] found that after participation in a neuromuscular training program, team handball players showed significant improvements in their dynamic-balance capabilities. Paterno, Myer, Ford and Hewett [20] found improvements in single-limb total stability and anteroposterior stability in female high school athletes after a 6 weeks neuromuscular training program.

However, there have been a limited number of studies investigating youth basketball players, especially in the pre-pubescent stage, specifically addressing basketball skill performance to ascertain changes in motoric skills after implementation of a neuromuscular training program. Therefore, it is important to determine the effects of neuromuscular training on motoric and basketball skills in pre-pubescent male basketball players. Accordingly, the objective of the present study was to examine the effect of an in-season, 8 weeks neuromuscular training program on motoric and selected basketball skills in pre-pubescent male basketball players. We hypothesized that the neuromuscular training group would exhibit significant improvement in motoric and basketball skills compared with a control group that simply maintained a regular training program.

## 2. Materials and Methods

### 2.1. Subjects

Twenty four male basketball players volunteered to participate in the study and were divided into two homogeneous groups according to pre-test results: intervention group ( $n = 12$ , age =  $10.7 \pm 0.75$  years, body height =  $148.9 \pm 9.14$  cm, body weight =  $40.8 \pm 11.54$  kg, training experience =  $3.1 \pm 1.28$  years), and control group ( $n = 12$ , age =  $10.8 \pm 0.68$  years, body height =  $149.8 \pm 7.71$  cm, body weight =  $44.4 \pm 8.04$  kg, training experience =  $2.5 \pm 1.69$  years). Exclusion criteria were chronic ankle instability and any lower extremity musculoskeletal injuries in the previous 6 months. All testing and training procedures were fully explained, and participants (or their parents in underage players) signed written informed consent before the beginning of the study. The study was conducted according to the declaration of Helsinki.

### 2.2. Motoric Skill Tests

#### 2.2.1. Agility T-Test

The Agility T-test was administered as originally set out by Semenick [21]. Four cones were arranged in a T shape, with a cone placed 9.14 m from the starting cone and 2 further cones placed 4.57 m on either side of the second

cone. All times were recorded using an electronic timing gate (Fitness Technology Inc.), a height of 0.75 and 3 m wide in line with the marked starting point. Trials were deemed unsuccessful if participants failed to touch a designated cone, crossed their legs while shuffling or failed to face forwards at all times. The recorded score for this test was the better of the two last trials.

#### 2.2.2. Sprint Test

A 20 meters (m) distance was selected to evaluate running performance. Participants performed 2 maximal sprint efforts over the distance of 20 m in an indoor sport hall with a 3-minute interval between trials. The best (the lowest time) of the 2 sprints was used for further analyses. Boys were encouraged to sprint as fast as possible. Sprint times were recorded to 0.001 second accuracy by an electronic chronometer.

#### 2.2.3. Back Strength Test

Isometric back strength of the subjects was measured with a digital back dynamometer (TKK 5402, Takei Scientific Instruments, Japan). The test is repeated three times, and the best score is recorded.

#### 2.2.4. Vertical Jump Test

In the test, the subject jumped from a standing position using a countermovement [22]. The participants' standing reach was recorded before the initial jumps took place. To measure vertical reach, each subject stood beside the instrument and extended her dominant arm over her head without lifting her heels off the ground. This height was recorded and later subtracted from the maximum height jumped to calculate the subject's vertical jump. Participants performed each jump 3 times, and the average of the 3 trials was recorded.

#### 2.2.5. Standing Long Jump Test

All subjects were instructed to perform a long jump from a standing position. Standardized instructions were given to subjects that permitted them to begin the jump with bent knees and swing their arms to assist in the jump. A line drawn on a hard surface served as the starting line. The length of the jump was determined using a tape measure, which was affixed to the floor. Each subject was given 3 trials, and the distance of the best jump was measured, to the nearest 1 cm, from the line to the point where the heel closest to the starting line landed. If the subject fell backward, the distance where the body part closest to the starting line touched the ground was measured as the jump's length. Each subject performed 3 jumps, whether or not a subject fell backward during an attempt. The longest jump was used as the test score.

#### 2.2.6. Sit and Reach Test

This test involves sitting on the floor with legs out straight ahead. Feet (shoes off) are placed flat against the

box. Both knees are held flat against the floor by the tester. The athlete leans forward slowly as far as possible toward a graduated ruler held on the box from -25 to +25, holding the greatest stretch for 2 seconds. The tester has to be sure that there are no jerky movements on the part of the subject and that her fingertips remain at the level and the legs flat. The score is recorded as the distance before (negative) or beyond (positive) the toes. The test is repeated twice, and the best score is recorded [23].

#### 2.2.7. Standing Stork Balance Test

Participants stood with hands on hips and were instructed to lift 1 leg and place the sole of the foot on the inner thigh of the other leg. On command, participants raised the heel of the straight leg to stand on the toes. Participants were required to balance for as long as possible without the heel of the foot touching the ground, or the other foot moving away from the knee. The test was repeated on the other leg. The test was timed (s) using a stopwatch [24].

### 2.3. Basketball Skill Tests

#### 2.3.1. Dribble Test

The dribbling test was part of The American Alliance for Health, Physical Education, Recreation and Dance (AHPEERD) basketball skill battery. Each subject performed three trials the first as a practice trial and the last two scored for the record. An obstacle course marked by the six cones was set up in the free throw lane of the court. Participant dribble around 6 cones using fingertips until the finish line was crossed by both feet. Scores was recorded to the nearest 0.10 of a second for each trial and the final score will be the sum elapsed time of the two trials. The test-retest reliability for dribbling skill test was ( $r=0.81$ ) [25].

#### 2.3.2. Shooting Test

Harrison Basketball Test was used to determine shooting performance of participants. Harrison has developed a four-item basketball test for boys. These four items consist of scoring, passing, dribbling and rebounding. Participants try to throw as many shots as possible in 30 seconds. At the end of the two attempts given during the test, the highest score was recorded [26].

### 2.4. Procedures

The neuromuscular training program was developed by one of the investigators supervising the training sessions on the basis of his experience [27]. The intervention group performed neuromuscular training twice a week for 8 weeks on tuesdays and thursdays, and after ended (NTP), they continued to train basketball training with control group. On monday and wednesday, they just trained basketball training. Before every training session, there was a warm-up consisting of a whole body consecutive dynamic, strengthening, and stretching exercises performed as a part of the intervention program. There were two batteries of exercises, performed always in the same order, which included agility, balance, strength, and plyometric components (Table 1).

The first battery consisted of five isometric exercises, primary focused on knee flexors, hip extensors and abdominal muscles, and three dynamic exercises which followed right after three specific isometric exercises. Second battery was the whole body circuit training (2 rounds, 30 seconds/exercise) consisted of the combination of dynamic and static movements on 6 stations while using the following exercise equipment: Bosu ball, swiss ball, balance disc and kettlebell.

**Table 1.** Neuromuscular Training Program

Warm up	First battery of exercises	Second battery of exercises
● Heel walking – 10 meters	● Isometric squat – 15 sec hold + 6 squat jumps	● Isometric forward lunge (balance disc under front foot) – 15 sec hold for each leg
● Toe walking – 10 meters	● Plank – 30 sec hold	● Straight arm plank on Swiss ball
● Forward lunges with trunk rotation – 12 reps	● Isometric forward lunge – hold 15 sec + 6 reverse lung for each leg	● Isometric squat on reversed Ball-Dynaso bosu balance trainer
● Inchworm push up – 6 reps	● Isometric push up – 10 sec hold + 6 push up	● One leg deadlift using kettlebell in hand
● Rollovers into V-sits – 6 reps	● Isometric single leg hip bridge – 15 sec hold for each leg	● Glute bridge with alternating front kicks (legs on reversed Ball-Dynaso bosu balance trainer)
● Spiderman lunges with vertical rotation – 8 reps		● Side to side jumps
● Bent knee iron cross – 12 reps		
● Squat to stand – 8 reps		
● Straight leg raises – 8 reps each leg		
● Groiners – 10 reps		
● Leg swings front-to-back & side-to-side – 10 reps each leg		
● Jumping jack – 10 reps		

Twice a week, the (NTP) was performed as a part of the standard training session. The maximal duration of the (NTP) (i.e., both batteries, including warm up) was 30 minutes per session. The control group performed basketball training 4 times a week. The control group was performing a conventional warm-up with the other strength and conditioning coach during the whole intervention program. Later, both groups continued to apply the standard basketball training program designed by the coach. The standard training session lasted 90 minutes.

**2.5. Statistical Analyses**

All statistical analyses were performed using the SPSS version 21.0 software (Statistical Package for Social Sciences; SPSS Inc., Chicago, IL, USA). All data were normally distributed (Skewness and Kurtosis values), and therefore, paired sample t-test was used to detect differences for each test between the pre-test and post-test to determine statistical significance. Cohen's d is used to describe the standardized mean difference of an effect size. A commonly used interpretation is to refer to effect sizes as small (d = 0.0-0.2), medium (d = 0.3-0.5), large (d = 0.6-0.8) and very large (0.9-1.5) based on benchmarks suggested by Cohen [28]. Two way repeated measures analysis of variance (ANOVA) was performed to test the combined effect of group (intervention and control) and measure (pre-test and post-test). Effect size was assessed by partial eta squared ( $\eta^2$ ) as follows: small effect –  $\eta^2 \leq 0.2$ , medium effect –  $\eta^2 \leq 0.6$ , large effect –  $\eta^2 \leq 1.2$ ,

very large effect –  $\eta^2 \leq 2.0$  [29]. The level of significance was set at  $p \leq 0.05$ .

**3. Results**

A significant difference was found between pretest (Mean = 25.6) and posttest (Mean = 26.91) of vertical jump averages ( $t(11) = -2.385, p < 0.05$ ). Calculated effect size of ( $d = -0.36$ ) shows that this difference is medium. Significant difference was found between pretest (Mean = 13.4) and posttest (Mean = 13.3) of flexibility averages ( $t(11) = -3.963, p < 0.05$ ). Calculated effect size of ( $d = 0.00$ ) shows that this difference is small. There was no significant difference in comparison of pretest and posttest values of other motoric skills and basketball skills ( $p > 0.05$ ). (Table 3).

There was no significant difference in comparison of pre-test and post-test of dribble averages ( $p > 0.05$ ). There are significant differences between the pre-test and post-test averages of all motoric skills and shooting skill ( $p < 0.05$ ). (Table 4). As a result of two-factor analysis of variance for repeated measures to determine whether or not a neuromuscular training group has a significant effect on motoric and selected basketball skills, (group x measurement) common effect differs in agility, back strength, long jump, flexibility and balance scores in favour of the intervention group (respectively,  $F_{(1,22)} = 6.93$ ;  $F_{(1,22)} = 4.10$ ;  $F_{(1,22)} = 5.88$ ;  $F_{(1,22)} = 7.09$ ;  $F_{(1,22)} = 10.18, p < 0.05$ ). (Table 5).

**Table 2.** Statistical Data of Participants' Descriptive Values

Variables	Control group n=12		Intervention group n=12		Total group n=24	
	Mean	Sd	Mean	Sd	Mean	Sd
Age (y)	10.8	0.68	10.7	0.75	10.7	0.71
Training experience (y)	2.5	1.69	3.1	1.28	2.8	1.50
Body height (cm)	149.8	7.71	148.9	9.14	149.3	8.28
Body weight (kg)	44.4	8.04	40.8	11.54	42.6	9.89

y= year; cm= centimeter; kg= kilogramme; Sd= standard deviation

**Table 3.** Comparison of Pre-Test and Post-Test Values of Motoric and Basketball Skills in the Control Group

Variables	Pre-test		Post-test		df	t	p	d	
	Mean	Sd	Mean	Sd					
Motoric skills	Agility (s)	12.8	0.89	13.0	0.81	11	-1.182	0.26	-
	Speed (s)	4.3	0.13	4.3	0.13	11	2.091	0.06	-
	Back strenght	59.6	16.93	63.2	17.33	11	-1,203	0.25	-
	Vertical jump (cm)	25.7	3.44	26.9	3.47	11	-2,385	0.03	-0.36
	Long jump (cm)	152.4	16.91	153.8	17.23	11	-1,856	0.09	-
	Flexibility (cm)	13.4	5.77	13.4	6.54	11	-3,963	0.00	0.00
	Balance (s)	4.1	1.99	4.2	2.27	11	-0.177	0.86	-
Basketball skills	Dribble (s)	20.9	1.89	20.8	1.64	11	0.806	0.43	-
	Shooting (n)	5.7	2.76	7.1	3.05	11	-2,072	0.06	-

$p < 0.05^*$  s= second; cm= centimeter; n= success shooting score; d= Cohen's d effect size

**Table 4.** Comparison of Pre-Test and Post-Test Values of Motoric and Basketball Skills in the Intervention Group

Variables	Pre-test		Post-test		df	t	p	d	
	Mean	Sd	Mean	Sd					
Motoric skills	Agility (s)	12.8	0.97	12.3	1.03	11	2.356	0.03	0.49
	Speed (s)	4.1	0.23	4.0	0.27	11	2.296	0.04	0.27
	Back strenght	54.3	14.29	68.0	16.26	11	-3.414	0.00	-0.89
	Vertical jump (cm)	29.0	4.72	30.5	4.75	11	-2.367	0.03	-0.31
	Long jump (cm)	161.4	22.81	166.3	23.50	11	-4.029	0.00	-0.21
	Flexibility (cm)	14.6	5.54	19.5	5.61	11	-5.034	0.00	-0.86
	Balance (s)	4.4	2.76	9.6	6.37	11	-3.905	0.00	-1.06
Basketball skills	Dribble (s)	18.8	1.39	18.8	1.58	11	0.223	0.82	-
	Shooting (n)	8.7	2.38	10.5	2.27	11	-3.344	0.00	-0.79

p<0.05\* s= second; cm= centimeter; n= success shooting score; d= Cohen's d effect size

**Table 5.** Pre-Test and Post-Test Anova Results of the Motoric and Basketball Skill Scores of the Groups

Variables	Group x Measure						Error			
	Sum of sq.	df	M. square	F	p	$\eta^2$	Sum of sq.	df	M. square	
Motoric Skills	Agility (s)	1.21	1	1.21	6.93	0.01	0.24	3.84	22	0.17
	Speed (s)	0.00	1	0.00	2.68	0.11	0.10	0.07	22	0.00
	Back strenght	307.54	1	307.54	4.10	0.05	0.15	1649.57	22	74.98
	Vertical jump	0.18	1	0.18	0.09	0.76	0.00	44.62	22	2.02
	Long jump (cm)	36.40	1	36.40	5.88	0.02	0.21	136.06	22	6.18
	Flexibility (cm)	24.79	1	24.79	7.09	0.01	0.24	76.94	22	3.49
	Balance (s)	77.75	1	77.75	10.18	0.00	0.31	167.88	22	7.63
Basketball Skills	Dribble (s)	0.01	1	0.01	0.02	0.88	0.00	12.18	22	0.55
	Shooting (n)	0.75	1	0.75	0.35	0.56	0.01	47.16	22	2.14

p<0.05\* s= second; cm= centimeter; n= success shooting score; sum of sq= sum of square; m.sguare= mean sguare;  $\eta^2$ = partial eta squared

## 4. Discussion

The purpose of the present study was to determine the effects of neuromuscular training combined with basketball training on motoric and basketball skills of pre-pubescent male basketball players.

At the end of the 8 weeks training period, a significant difference was found in pre-test and post-test parameters, including vertical jump and flexibility, in the control group that only performed basketball training. This significant difference may be explained by the basketball training program, which focused on technical skills such as vertical jump, flexibility, and lower limb exercises planned by the coach. It is apparent that there are many benefits of basketball including increased physical fitness, building self-esteem, developing motor coordination and self-discipline, facilitating mental development and concentration, and increasing flexibility, speed, and agility [30].

In the intervention group, however, we found significant differences between pre- and post-test results in all motor skills investigated in this study. Studies have reported that neuromuscular training is likely to enhance athletic

performance [31,32]. Chappell and Limpisvasti [33] found that a 6 weeks (NTP) resulted in significant improvement in vertical jump height in female collegiate athletes. Myer et al. [34] studied the effect of a neuromuscular training program on measures of athletic performance and lower-extremity movement biomechanics in female athletes, especially female basketball players, and found significant improvement in measures of athletic performance. In addition, they also found significant differences between pre-test and post-test results of shooting performance in basketball skills: the intervention group, in particular, exhibited significant improvement in shooting skill, with improvement in performance scores of approximately 20% to 25%. This was likely due to improvement of lower limb strength and core stability, which is important, and, in turn, led to improvement in athletic performance. In a study by Ahmed [35], the neuromuscular training group exhibited significant improvement in skills performance, which were assessed by measuring dribbling, passing, defense, and speed spot shooting skills. A neuromuscular training program helps to maintain balance and improve body flexibility, strength and fitness levels, thus contributing to improvement of

skills performance [35]. These findings suggest that all motor and shooting skills in the intervention group were positively affected by the 8 weeks neuromuscular training program that focused on balance training, strength, plyometric, agility, running exercises, and stretching.

According to the results of variance analysis, the effect of (group x measurement); agility, back strength, long jump, flexibility, and balance were significantly higher in the experimental group compared to the control group. It can be concluded that basketball training combined with neuromuscular training has positive effects on motoric skills. The (NTP) improved athletes' ability to control their center of mass during dynamic activity and enhance neuromuscular control of the trunk, which influences dynamic stability of the lower extremities during high-speed athletic maneuvers [36]. The study by Ahmed [35] assessed the effect of a neuromuscular training program in improving the musculoskeletal fitness of young male basketball players. The results demonstrated that the neuromuscular training group exhibited a greater percentage of improvement in musculoskeletal fitness than the control group, which trained only with regular exercises. The results also demonstrated significant differences in the post-test measurements of the two groups. Sue et al. [37] reported that a 6 weeks (NTP) improved abdominal endurance in junior tennis players. The main findings of Hopper et al. [38] study were that the 6 weeks neuromuscular training intervention significantly improved sprint and change of direction speed, countermovement jump height, and peak power, and movement competency in 11-14 years-old netball players. Faigenbaum et al. [39] reported that after the completion of 8 weeks (NTP) by grade 2 children, significant improvements were found in push-ups, curl ups, long jump, single leg hop, and running performance. In addition, Noyes et al. [40] reported significant improvements in vertical jumping performance after 6 weeks of neuromuscular training undertaken by 14-17 years-old female basketball players. The results of these studies support the findings of our study.

The current study has some limitations. In our study, the age of the sample group was limited to the pre-pubertal period. Neuromuscular training can be applied to the basketball players in the older age groups, its effect on their skills can be determined and the improvement of skills in different age groups can be compared. Since basketball training applied to the control group shows similarities with neuromuscular training content such as running, jumping, sliding and balance training, it can be considered as a limitation that may affect the results of the study. The study was also limited by the relatively small sample size. A higher number of control and intervention groups can be applied to create the study.

## 5. Conclusions

Based on findings from this study, a (NTP) demonstrated significant effects on motoric and shooting skills in pre-pubescent male basketball players. The results of this study highlight the potential of using neuromuscular training, along with basketball training, to improve performance of motoric and basketball skills, especially in pre-pubescent male basketball players.

It is recommended that coaches incorporate this type of training into young athletes' normal training and exercise routines because it is effective in improving performance levels. This training method, which is recommended to be used in the warm-up section of the training especially in season, is important in terms of adding diversity to training. During the season, the condition of the basketball players can be maintained at the highest level by combining normal basketball training with this training.

## Conflicts of Interest

The authors declare no conflict of interest.

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