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Original article

The Effect of Plyometric Training Performed on Different Surfaces on Some Performance Parameters

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Abstract. *Study Objective:* This study aimed to examine the effects of plyometric training performed on different surfaces on some performance measurement parameters in basketball players and compare them. *Methods:* Experimental design with the pretest-posttest control group, which was one of the real experimental models, was used in the study. Using simple random sampling, one of the random sampling methods, 48 male basketball players were divided into aqua (n=12), grass surface (n=12), parquet surface (n=12), and control groups (n=12). In the study, after the plyometric training, on-court basketball technical training was applied to the experimental groups. On the other hand, only basketball technical training was applied to the control group. Height, body weight, vertical jump, long jump, balance, agility, flexibility, speed, and anaerobic power measurements were taken before and after the training. *Results*: In the pre-test and post-test comparisons within the group, the difference was significant in balance and sprint measurement, except for the control group, in the aqua group in the flexibility measurement tests, in all groups in the vertical jump and long jump measurements, and in the aqua, grass and parquet surface groups in the agility measurement ($p<0,05$) was found and it was determined that the best improvement was in favor of the group working in water. *Conclusions*: As a result, it can be said that plyometric exercises applied in aqua, grass, and parquet surfaces will positively improve the vertical jump strength, agility, balance skills, long jump, and anaerobic power performance of 12-15 age-group basketball players.

Key words: plyometric, aqua, grass surface, parquet surface, basketball

Introduction

The word "Plyometric" comes from the Greek word "pleythyein", which means to increase or multiply plyometrics (1). It is used to describe exercises that allow athletes to take advantage of the stretch-shortening cycle to create an explosive movement (2). In running and jumping movements, the muscles first contract eccentrically, then concentric contraction follows. This combination of eccentric and concentric motion is defined as the stress-shortening cycle. Plyometric exercises consist of eccentric, amortization, and concentric contraction phases. In the eccentric phase, the muscle-tendon units of the agonist and synergist muscles in the lower extremity are stretched as a result of the load and the kinetic energy created in the joint. Stretching of the muscle-tendon unit during the eccentric phase results in an increase in both performance and strength generation, which creates the strain-shortening cycle. The time between the cessation of the eccentric stress and the beginning of the concentric movement is called the amortization phase. It represents the delay time between the negative workload of eccentric stretching and muscle movement, including elastic recovery, to generate force in the plyometric movement. This phase, which plays a key role, is very important for improving performance. Prolonging the amortization phase will ensure that the accumulated energy is wasted as heat. Immediately after the amortization phase, the concentric phase occurs with the shortening of the muscle-tendon unit. This phase is the functional phase of plyometric exercise with force generation. It occurs as a result of multiple interactions, including biomechanical responses using the elastic structures of previously stretched muscles in the concentric phase, which is the last stage of plyometric movement (3-7).

Due to the support of intramuscular coordination with plyometric exercises, it performs a rapid and distinct maximal strength change without any change in muscle mass or body weight, which is preferred in all sports branches that explosive strength has an important place (8, 9). Since many basketball trainers argue that vertical jump and leg strength are the basis of superior performance, they also attach importance to methods that accelerate muscle response and plyometric exercises (10). In terms of being a basis for strength training, it is stated that it would be better to perform plyometric exercises at the beginner level in adolescent athletes and the intermediate level in advanced ages (11).

Plyometric training is a versatile method. Therefore, plyometric training can be performed on surfaces with different properties (12). The choice of the training surface can affect injuries, as well as change the effects of plyometric training. The hardness of the surface where bounces, jumps, and other explosive movements are performed can affect the amortization stage by extending or shortening the contact time with the ground (7). In this study, the effects of plyometric training on different surfaces were examined and it was aimed to investigate which one would have better results by predicting the differences in the amortization stage between the soils. In this context, this study aimed to examine the effects of plyometric training on parquet surface, grass surface, and aqua on some performance parameters on 12-15 age-group basketball players.

Material and Methods

Participants

The study was approved by the Mersin University Ethics Committee and adhered to the Declaration of Helsinki. Before the participation, the necessary permissions were obtained from the sports clubs and the necessary permissions from the athletes' parents, and the study was conducted with a total of 48 male athletes aged 12-15, who did not have any knee and ankle beard before, and who had at least two years of licensed basketball player history. Participants were divided into 4 groups as control (n=12), aqua (n=12), grass surface (n=12), and parquet surface (n=12) (Table 1). In the determination of the groups, it was determined by using simple random sampling, which was one of the random sampling methods.

Procedure

In the study, only basketball technical training was applied to the control group for 8 weeks, and plyometric training + basketball technical training was applied to the experimental groups. Plyometric exercises (10 minutes warm-up, 20 minutes main phase, and 10 minutes cool-down) were applied to the experimental groups two days a week before basketball training (Table 2). Basketball technical training (10 minutes warm-up, 40 minutes main phase, and 10 minutes cool-down) was applied to all study groups four days a week. The Aqua group participated in

Table 1. Some Anthropometric Measurements of the Participants

Parameters	Aqua Group (n=12)	Grass Surface Group (n=12)	Parquet Surface Group (n=12)	Control Group (n=12)
Age	13.33±1.15	13.08±.79	13.17±1.11	13.58±.90
Weight (kg)	50.87±12.63	58.19±11.16	55.36±18.98	57.71±7.33
Height(cm)	160.50±13.24	165.75±9.41	163.83±16.55	166.75±6.38
BMI (kg/m^2)	19.35±2.53	20.64±3.29	19.83±3.25	20.58±1.71

the plyometric exercises with bare feet and the other groups with sports shoes. For each athlete in the Aqua group, the sections up to the knee levels were determined on the pool surface where the plyometric study would be performed. Before the plyometric exercises, the movements were explained to the athletes theoretically and then shown practically. It was stated that the athletes were asked to make the best jumps during and before the practice to ensure effective participation before the plyometric exercises. After the end of the plyometric studies, 15 minutes were given to prepare the athletes, and basketball technical and tactical training was applied in the gym

Training Plan

Performance Measurements

To the control and experimental groups before and after the study; vertical jump test, flamingo balance test, lane agility test, sit and lie down flexibility test, 20 meters sprint test, standing long jump and anaerobic power tests were applied.

Vertical Jump Test: The vertical jump measurements of the athletes were measured with the electronic jump Microgate optojump, of which validity and reliability (14) were made. Athletes took a position on the electronic jump text with their knees bent and hands in a free position, and when they felt ready, they made two intermittent jumps upwards. The best grades were recorded in cm.

Balance Test: The balance measurements of the athletes were measured with the Flamingo balance instrument, of which the validity and reliability (15) were made. The athletes were asked to bend the knee of their non-dominant foot backwards pull it towards the hip, and hold it with the hand on the same side. The time was stopped when the balance disturbed (if he/she released the gripped foot, touched the ground, fell off the balance board). After the athlete got on the balance board and regained his/her balance, the time was resumed from the second it stopped. The test was continued in this way for one minute (16, 17). Each balance attempt of the athletes (losing their balance) was counted, and this number was recorded as the score of the research group at the end of the test.

Agility Test: The lane agility test, which was a basketball-specific agility test, was used especially by NBA teams in player selection (18). To determine the agility of the athletes, the lane agility test, which validity and reliability was performed by (19), was used. For the measurement, it was recorded in seconds with a WT 3540 brand photocell stopwatch. The test was repeated twice, and the best grade was recorded on the form in seconds.

Flexibility Test: Athletes tried to achieve the best extension by sitting on the floor with their feet flat in front of the test bench and placing their hands on top of each other with their knees tense and palms facing

Table 2. Plyometric movements

Movements	**1st Week**	**2nd Week**	**3rd Week**	**4th Week**	**5th Week**	**6th Week**	**7th Week**	**8th Week**
Toe jump	2x8	2x8	2x10	2x10	2x10	2x12	2x10	2x10
Double foot left-right jump on the line	2x8	2x8	2x10	2x10	2x10	2x10	2x10	2x10
Leap and stretch in place	2x8	2x8	2x10	2x10	2x10	2x10	2x10	2x10
Leap by step	2x8	2x8	2x10	2x10	2x10	2x10	2x10	2x10
Pulling one knee to chest	2x8	2x8	2x10	2x10	2x10	2x10	2x10	2x10
Double feet knees to chest			2x10	2x10	2x10	2x10	2x10	2x10
Squat jump					2x10	2x10	2x10	2x10
Split squat jump							2x10	2x10
Total jumps per day	80	80	120	120	140	168	192	192
Total jumps per week	160	160	240	240	280	336	384	384
Rest Between Sets	2 min	2 min	2 min	2 min	2 min	2 min	2 min	2 min

the ground. They were asked to wait for 2 seconds while the movement was taking place (20). Before the measurements, the movement was shown to the athletes practically and after the trial phase, each athlete applied the test twice. In the evaluation, the best grade of the athlete was recorded in the measurement form in cm.

Sprint Test: When the athletes were ready, they finished the test with maximum speed by making a rapid exit at a distance of 20 meters. The measurements of the athletes were recorded in seconds with the WT 3540 brand photocell stopwatch. Each athlete performed the test twice, the best result was recorded on the measurement form.

Long Jump Test: The distance between the heel of the left foot after contacting the ground by jumping forward as far as possible with the swing of the arms, with the arms in the semi-squat position just behind the determined line, was measured with meters (21). Each athlete applied the test twice and their best scores were recorded in cm.

Anaerobic Power: To calculate the anaerobic power of the participants; P= [√4,9(bodyweight kg)] x √vertical jump distance (m.) x 9.81 Lewis formula was used (22).

Statistical analysis

The obtained data were analyzed with the SPSS package program. The distribution of the data was analyzed with the Shapiro Wilk test. As a result of the test, it was determined that the data did not show normal distribution, and the data were analyzed with non-parametric tests. Descriptive statistics, Mann Whitney U-Test for pairwise comparisons, Kruskal-Wallis Test for multiple groups were used in the analyses. Non-parametric Wilcoxon Paired-Sample Test was used to determine the significance of the difference between the pre-test and post-test for each group. Differences between groups (posttest and post-pretest differences) were made with the non-parametric Mann-Whitney U test. Significance levels were evaluated according to $p<0.05$.

Results

The results obtained from the study and the statistical analysis of these results were presented in the following tables.

As can be seen in Table 3, while the difference in balance, sprint, and agility parameters was significant in all groups except the control group, the difference was significant in flexibility only in the aqua group. The difference between the pretest and posttest in the vertical jump, long jump, and anaerobic power variables were significant in all groups ($p<0.05$).

As seen in Table 4, after 8 weeks of training on different surfaces, according to the difference between the performance measurements of the participants, in vertical jump; In the agility parameter, the grass, parquet surface, and control group of the aqua group, and the control group of the grass and parquet surface working groups; standing long jump and anaerobic power; in parameters; Statistically significant difference was found between the group working in aqua and the parquet and control group, and the groups working on grass and parquet surfaces with the control group ($p<0.05$).

Discussion and Conclusion

In this study, a difference was found in the vertical jump in all groups (Table 3). There were many studies supporting this significant difference in studies on plyometric training (13,18,23,24,25,26). It was seen that the highest increase between the pre-test and post-test in the experimental groups was in the aqua group. There are also studies supporting these results (27,28,29,30). This may be since, unlike other groups, water-resistance during training in the aqua group required extra force applications to take the feet of the athletes out of the water. Moreover, since the group athletes working in the water exercised in water for the first time, it enabled them to be more willing and concentrated than the athletes working on other surfaces, so it may have improved their vertical jump performance more positively.

There was a significant difference between the pretest and posttest scores of the long jump test in all groups (Table 3). Studies were supported that plyometric exercises also increased long jumps such as vertical jumps are frequently encountered (11,27,31,32,33,34,35). Besides, the difference in anaerobic power pre-test and post-test scores was found

Table 3. Wilcoxon Signed Ranks Test Results of Participants' Pre-Test-Post-Test Measurement Values

Variables	Groups	N	Pre-Test ($\bar{X}$±SS)	Post-Test ($\bar{X}$±SS)	Z	p
Balance	Aqua Group	12	2.17±1.26	1.25±96	-2.636	.008*
	Grass Surface	12	3.25±1.35	2.08±.99	-2.558	.011*
	Parquet Surface	12	2.92±1.62	1.92±1.24	-2.460	.014*
	Control Group	12	2.75±.96	2.50±.67	-1.342	.180
Sprint	Aqua Group	12	3.61±.37	3.45±.33	-2.080	.037*
	Grass Surface	12	4.00±.41	3.83±.41	-2.589	.010*
	Parquet Surface	12	4.00±.43	3.81±.49	-2.118	.034*
	Control Group	12	3.59±.48	3.49±.40	-1.735	.083
Vertical Jump	Aqua Group	12	31.65±5.49	36.64±6.07	-3.061	.002*
	Grass Surface	12	30.07±4.50	33.76±4.73	-3.061	.002*
	Parquet Surface	12	29.02±4.91	32.35±5.12	-3.064	.002*
	Control Group	12	30.34±3.34	31.67±3.25	-3.063	.002*
Agility	Aqua Group	12	15.02±2.21	13.41±2.30	-3.061	.002*
	Grass Surface	12	15.53±1.67	14.94±1.73	-2.353	.019*
	Parquet Surface	12	16.29±1.61	15.78±1.61	-1.961	.050*
	Control Group	12	15.14±.89	15.13±.80	-.078	.937
Flexibility	Aqua Group	12	28.75±5.25	29.16±5.34	-2.041	.041*
	Grass Surface	12	27.12±4.46	27.75±4.75	-1.932	.053
	Parquet Surface	12	26.67±6.19	26.75±4.02	-.045	.964
	Control Group	12	28.70±3.68	28.75±3.73	-.071	.943
Long jump	Aqua Group	12	170.08±32.90	177.67±32.08	-3.077	.002*
	Grass Surface	12	156.00±32.21	161.58±33.11	-3.075	.002*
	Parquet Surface	12	151.00±33.73	155.75±34.13	-3.071	.002*
	Control Group	12	162.25±19.77	163.67±20.22	-2.699	.007*
Anaerobic Power	Aqua Group	12	626.06±188.67	669.32±197.15	-3.059	.002*
	Grass Surface	12	691.09±138.97	727.46±144.93	-3.059	.002*
	Parquet Surface	12	653.30±248.30	682.31±252.99	-3.059	.002*
	Control Group	12	690.93±106.33	701.09±106.70	-2.824	.005*

*p<0.05

Table 4. Kruskal Wallis-H Test Results According to the Difference Between Pretest-Posttest Scores of Performance Measurement Values

Variables	Groups	N	Rank Averages	df	X^2	p	Difference Between Groups
Vertical Jump	Aqua Group	12	39.38	3	34.408	.000*	1-2, 1-3, 1-4, 2-4, 3-4
	Grass Surface	12	28.38				
	Parquet Surface	12	23.75				
	Control Group	12	6.50				

Table 4 (*Continued*)

Variables	Groups	N	Rank Averages	df	X^2	p	Difference Between Groups
Balance	Aqua Group	12	23.04	3	5.923	.115	
	Grass Surface	12	20.58				
	Parquet Surface	12	22.00				
	Control Group	12	32.38				
Agility	Aqua Group	12	8.88	3	23.838	.000*	1-2, 1-3,1-4
	Grass Surface	12	25.71				
	Parquet Surface	12	27.25				
	Control Group	12	36.17				
Flexibility	Aqua Group	12	26.46	3	2.911	.406	
	Grass Surface	12	29.08				
	Parquet Surface	12	21.17				
	Control Group	12	21.29				
Sprint	Aqua Group	12	23.75	3	1.069	.785	
	Grass Surface	12	23.21				
	Parquet Surface	12	22.96				
	Control Group	12	28.08				
Long Jump	Aqua Group	12	37.17	3	29.298	.000*	1-3, 1-4, 2-4, 3-4,
	Grass Surface	12	29.96				
	Parquet Surface	12	23.13				
	Control Group	12	7.75				
Anaerobic Power	Aqua Group	12	36.00	3	27.878	.000*	1-3, 1-4, 2-4, 3-4
	Grass Surface	12	30.92				
	Parquet Surface	12	23.33				
	Control Group	12	7.75				

*p<0.05

to be significant in all groups, showing that plyometric exercises also affect anaerobic power indirectly by improving jumping ability (18,36,37,38). Miller, Berry, Bullard, and Gilders (2002) stated that Aqua plyometric training would be an alternative way to increase performance like other plyometrics (39). The reason for the significant difference in the control group may be that there were too many applications to improve jumping skills in basketball training, although plyometrics were not studied.

In the literature, it was stated that plyometric exercises including jumps and bounces increase balance performance due to the need for extra balance to perform the movements properly in athletes (17,40), but long-term exercises with high intensity affect balance performance negatively (41). In this study, plyometric studies were applied at the beginner and intermediate levels. For this reason, this study may have positively affected the balance performances of the experimental groups and supported the literature. The reason why there was no significant difference in balance skills in the control group may be due to the lack of extra applications or plyometric studies for balance skills.

In this study, it was found that plyometric exercises affected agility (Table 3). Plyometric-based strength exercises contributed to the development of agility (42,43). Yıldız et al. (2017) stated that agility was in a relationship according to the jumping protocols applied in the sports branch (44). Due to the specialization principle of the training, there was a relationship between the movements that the athletes perform in the branch and the direction of the movements, and agility. In the applied plyometric training protocol, the presence of forward and backward movements, as well as horizontal and vertical jumps, can increase agility performance.

According to the flexibility test score (Table 3), there was a significant change only in the aqua experimental group, based on the idea that the evaluation alone may be wrong, and that it should be evaluated together with the strength development; In the study of plyometric training, Ateş et al. (2007) provided the development of inter and intramuscular coordination, and as Uzuner (2016) stated, it may be since water exercises can increase the flexibility of the hamstring and gluteus maximus due to the increase in the flexibility of the connective tissues to which they were attached with the muscles (45,46).

Studies showed that plyometric exercises improve sprint performance, similar to Table 1 (18,38,47). Components such as stride frequency and stride length were very important in the development of speed (18). In plyometric studies, it may have increased the sprint value since it contains too much movement for the number of strides and jumps (contact with the ground).

In this study, when the pre-test and post-test data obtained by performing 8-week aqua, grass surface, and parquet surface plyometric training applied to the 12-15 age group basketball players were examined, it was seen that the plyometric training applied on different surfaces were the vertical jump, balance, agility, 20 m sprint. It was seen that it provided significant improvements in the long jump and anaerobic power parameters. It was seen that there was a significant difference in the flexibility parameter between aqua, grass, and parquet surfaces in favor of the aqua group. As a result of the data obtained, it can be said that plyometric exercises applied in aqua, grass, and parquet surfaces will positively improve the vertical jump strength, balance skills, 20 m sprint, long jump, and anaerobic power performances of basketball players. In this study on basketball players, it was seen that the outstanding results in terms of surface groups and performance parameters were in the aqua group (Tables 3 and 4). According to Davies et al. (2015), for an effective and high plyometric movement, the duration of the amortization phase should be short (42). They stated that the prolongation of the amortization phase can reduce the occurrence of an effective concentric contraction by preventing the stretch reflex from being active because the accumulated energy was wasted as heat. Although there was a prolongation in the amortization phase with the prolongation of the contact time to the ground due to the buoyancy of the aqua plyometric studies, while it was different from the other groups, and it was thought that the reason was the athletes applied extra force to take their feet out of the water due to the water resistance along with the friction. Besides, Katkat et al. (2009) stated that as the hardness coefficient of the surface increased during plyometric studies, muscle damage increased in athletes, and the recovery period prolonged (48). Moreover, Arazi, Eston, Asadi, Roozbeh, and Saati Zarei (2016) stated that aqua exercises would be beneficial for performance improvements with less muscle damage and pain (49). As a result, it can be concluded that aqua, grass, and parquet surfaces can be considered as alternatives to each other for plyometric studies and that the studies to be done can improve performance in 12-15-year-old basketball players positively, and it can be said that aqua plyometric studies up to knee level can be effective in plyometric studies to be done on different surfaces to improve the athletic performance of athletes.

However, in new plyometric studies, the training intensities to be applied to the athletes or the difficulty levels of the movements can be changed, as well as the diversification of the surfaces. Moreover, for aqua studies, power outputs and effects can be examined by measuring the amortization times according to the height differences of the water.

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