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Original Article

The effect of plyometric training plus arginine supplementation on injury prevention related to physical fitness level of beach soccer players

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Abstract

Background: The present study was conducted with the aim of determining the effect of plyometric exercises with arginine supplementation on some physical fitness factors of beach soccer players for the purpose of injury prevention.

Method: Based on the research entry criteria, 20 beach soccer players were selected and were randomly assigned to two groups of plyometric exercises (n=10) and plyometrics with arginine supplement (n=10). Then, age, height, weight, and physical fitness factors including aerobic and anaerobic capacity, muscle strength and endurance, and fat percentage of subjects were evaluated. The first training group received plyometric exercises with arginine supplement. In the second group, plyometric exercises were applied along with placebo. After 8 weeks of training, physical fitness factors were re-evaluated. The correlated T test was used to determine the intra-group changes and the ANCOVA test was used to compare between the groups. The obtained results were analyzed using SPSS version 26 software.

Results: The findings showed that both plyometric training programs with and without arginine supplementation had a significant effect on improving aerobic power ($P=0.002$, $P=0.001$), anaerobic power ($P\geq0.01$), muscle strength. ($P=0.001$), muscle endurance ($P=0.004$) and fat percentage ($P=0.001$). Also, the results of comparing the effects of two training programs show that there is a significant difference between the two training programs in the variables of aerobic power ($P=0.01$), anaerobic power ($P\geq0.05$) and fat percentage ($P=0.02$).

Conclusion: According to the results and previous studies, using two types of plyometric exercises, with and without using Arginine supplementation especially with arginine supplementation could be useful to prevent sports related injuries specially ankle and knee sprains and groin strain which are prevalent among soccer players of all types specially beach soccer players. It is explained by different mechanisms including affecting aerobic and anaerobic powers, muscle strength and endurance, and body fat.

Keywords: Plyometric training, Arginine Supplement, Sports Injury Prevention, Physical Fitness, Beach Soccer

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Introduction

Each year, a lot of money and time is spent on treating injuries caused by participating in sports. Due to the wide incidence of injuries, teams have to pay any costs to restore injured athletes to a proper state of health. Moreover, in some injuries, the individual may need to rest for more than a month in order to recover and this wasted time is not economical in professional sport (1).

Beach soccer is one of the sports which is held on the beach or on a field covered with sand. It is derived from soccer and same as soccer, technically and time of playing close to futsal, and in terms of the surface of the playing field and sand features, it makes it unique (2). Futsal and beach soccer are multiple-sprint sports (more high-intensity phases) that differs them from soccer (3). Ball direction changes are faster in futsal and beach than soccer which could impact knee joint demands. Match length differs between futsal (two periods of 20 minutes separated by a 10-min rest interval), beach (three periods of 12 minutes separated by 3-min rest intervals), and soccer (two periods of 45 minutes separated by a 15-min rest interval) and there are differences in ball dimensions (~ 420g to beach and field soccer, and ~250g to futsal). In addition, there are major differences between beach soccer and futsal in terms of playing surface (unstable versus rigid), techniques (beach soccer requires more acrobatic actions), running speed (beach soccer players are unable to run at high speed) and jump height (lower maximum force and take-off velocity in beach soccer because of compliance and surface instability). In this sport, players are not allowed to wear shoes, but it is possible to use wrist bandages around the ankle, foot, and wearing glasses to protect them. Because it is a contact sport that requires physical skills, technical and tactical attributes increase the incidence of injury (4). Naturally, it must involve different types of injuries with different mechanisms (5, 6, 7*)*. Altogether, these differences can generate different physiological adaptations in athletes, especially in musculoskeletal system. Despite these different adaptations, the most frequent injuries in the three sports are those that affect the knees, ankles, and thighs (5). The most common injuries of beach soccer were in lower extremities such as tendon injury, and foot/toe contusion (8), and in terms of the type of injuries, the strain was the most prevalent injury occurred (%33.33) (specially in ankle followed by groin and knee) (9).

In some research, it has shown that beach soccer players had strength asymmetry for extensor and flexor muscles, respectively. Mean H/Q ratio values for dominant and nondominant limbs in futsal, soccer, and beach players were lower than 0.6, which has been traditionally associated with a higher incidence of knee injuries (10). One of the most important injury preventive factors that can be mentioned are exercises that help improve exercise-related performance which enhance poor physical fitness and thus prevent them from injuries (11). Previous authors have shown that introducing a specific hamstring strengthening program during soccer training can reduce the incidence of hamstring injuries (12).

Plyometric is a type of training that includes dynamic and fast stretching of muscles (eccentric action), which is immediately followed by a concentric shortening action of the same muscles and connective tissues (13). These type of exercise is based on speed, strength and improvement of neuro-muscular coordination, and it seems that these important physical abilities plus balance, agility and coordination, have a significant effect on improving the speed in performing sports skills (14). In soccer, successful performance depends on fundamental abilities, in particular, repetitive explosive movements, strength, power, kicking, tackling and their derivatives such as jumping, turning, sprinting and changing pace which all play an important role in performance (15). Research has shown that plyometric training improves vertical jump performance, agility, and knee extensor strength in young soccer players (16). Also, short-term 6 weeks of plyometric exercises improved endurance performance compared to soccer training alone, and the improvements caused by plyometric exercises were not influenced by gender (17, 18). In a research, Michalidis determined the effect of plyometric and directional exercises on physical fitness parameters of youth soccer players. The results showed that the performance of players improved in acceleration, T-test and long jump in both groups. This study shows that a short-term combined program of plyometric training and COD[1] exercises can improve parameters of jumping ability, acceleration and endurance in young soccer players (19).

In the context of the importance of aerobic and anaerobic capacity in football, it has been reported that football is an intermittent sport that requires different physiological components (20). The dominant energy system in football is the aerobic system (maximal lactate steady state, maximal oxygen uptake (VO2max) while maintaining the balance between the processes of accumulation and removal of blood lactate) (21). Improvements in aerobic capacity (e.g. VO2max, running economy and lactate threshold) have been reported

[1] Change of direction

to correspond with increased physical fitness, technique and tactical performance of players. In addition, the capacity to produce a variety of powerful actions during a 90-minute game is associated with high aerobic capacity (20). Performance of various forms of HIIT by young adults and elderly patients for two to fifteen weeks resulted in significant increases in Vo2max between 4 and 46 percent (22). In addition to aerobic capacity, several short-term and maximally intense movements in football depend on anaerobic capacity (the ability of the body to use the phosphagen or lactic energy system) (21). A number of studies have shown that performing HIIT for 2 to 15 weeks leads to a significant increase in anaerobic capacity between 5 and 28 percent (22, 23, 24).

In addition, the increase in muscle strength (the amount of force produced by the muscle during a contraction) in beach soccer athletes, especially the strength of the lower limbs, is a necessary feature for the sport of soccer in order to achieve the height of the jump, hit the ball or the required movement during the performance (25). Also, it has been shown that there is a significant relationship between 1RM[1], movement acceleration and speed, which has important implications for training and performance (26, 27). Muscle strength can be increased through two different mechanisms: muscle hypertrophy and neural adaptation (28). Muscle hypertrophy is an increase in the cross-sectional area of the muscle, which increases its contractility. However, this typically results in greater body mass, which may not be desirable in players due to the additional load-carrying capacity that must be carried, which may reduce overall performance given that oxygen uptake is proportional with body mass (29). On the other hand, neural adaptation is a broad term that includes factors such as selective activation of motor units, synchronization of motor units, selective activation of muscles, ballistic contractions, increased rate coding (motor neuron discharge frequency) and increased reflex potential. It refers to the recruitment of motor units and the increase of simultaneous contractions of the antagonist muscles (30). Increasing strength through this mechanism typically results in minimal increases in body mass (28). It seems that one of the main physiological differences between athletes at different levels is their ability to generate maximal force and impact with high contraction speed while performing explosive movements. It is likely that by increasing the force of muscle contractions in the appropriate muscle groups, the acceleration and speed of functional skills may be improved (31). This may have significant implications for agility, speed retention and injury prevention.

[1] repetition maximum

According to Crozier et al., the deficiency in muscle strength is one of the main causes of muscle damage during exercise (32).

Dynamic stability through the neuromuscular system helps protect the knee joint during dynamic sports activities by controlling and coordinating muscle functions. Therefore, the agonist-antagonist relationship of the quadriceps and hamstrings is critical in preventing excessive knee motion and preventing ACL[1] injury during knee motion (33). Hamstring recruitment reduces ACL loads from the quadriceps and may contribute to dynamic knee stability by resisting anterior and lateral tibial slides and tibial rotations (34). A meta-analysis found that athletes with a hamstring muscle imbalance of 0.6 or lower were 17 times more likely to suffer a hamstring injury (35). According to the mentioned cases, it seems that strength and its improvement is important and fundamental in preventing injury and improving performance.

On the other hand, muscular strength has a close relationship with muscular endurance (the ability of a muscle or muscle group to maintain and sustain static or very intense repetitive exercises) (36). With increasing muscular strength, muscular endurance also increases. a person who can move a specific weight for a maximum of 25 repetitions, is very likely that can perform the maximum repetitions with that specific weight if the strength increases by 10%, because it becomes easier for that person to lift the weight (37). As a result, it is important to pay attention to strength training to increase muscular endurance. Adaptations related to muscular endurance training are the same adaptations related to the lactic acid system. Anaerobic exercise increases the activity of several key glycolytic and oxidative enzymes. In addition to improving performance, speed training with heavy weights saves muscle energy consumption. Anaerobic exercises improve muscle tolerance against acid accumulated in the anaerobic glycolysis stage. Considering that the lactic acid accumulated during speed training is one of the main factors of fatigue, the increase of tampons (bicarbonates and phosphates of muscle) removes hydrogenated ions and reduces the acidic state. In this case, the onset of fatigue in anaerobic training could be postponed. (38).

On the other hand, beach soccer players tend to have a body with a low fat mass. From the world health, it is recommended that the fat percentage of men should not be lower than 5% and higher than 25% and for women it should not be lower than 8% and higher than

[1] Anterior cruciate ligament

32%, otherwise they are at risk of developing diseases. Also, people whose fat percentage is high usually get a lower physical fitness test score than people who have a lower fat percentage (39). Previous studies have indicated that suboptimal body composition has negative impacts on several characteristics including both aerobic and anaerobic capacity, while also influencing injury risk (40, 41).

On the other hand, to achieve a balanced and muscular body, a lot of activity and training along with a long period of time is required. Because beach soccer players prefer to reach their sports goal as soon as possible, they use supplements (42). One of these common amino acid supplements is arginine, which has been shown to have positive effects on muscle protein metabolism (43). In healthy adults with sufficient protein intake, the endogenous synthesis of arginine will be sufficient to meet physiological needs; But under the conditions of intense exercise, the ability of endogenous production by the body will not be enough; Therefore, arginine is called a semi-essential or essential amino acid (44). Recent studies have shown that arginine plays a cellular signaling role in muscle tissue. There is also indirect evidence that arginine inhibits protein breakdown in skeletal muscle. Arginine supplementation is common among athletes, and arginine-containing supplements are marketed as nitric oxide stimulators that aim to increase muscle strength and endurance (45, 46). An increase in nitric oxide increases blood flow (47) and this could potentially be beneficial for people who do resistance training. In addition, increased blood flow could theoretically improve athletic performance by increasing nutrient delivery or removing waste products from the body (48). This amino acid plays an essential role in protein synthesis in the cytoplasm and nucleus and is responsible for the cycle of urea and other amino acids. In some cases, it has been shown that receiving external arginine as a food supplement can maintain body fat-free mass and improve functional capacity (49). L-arginine improves the immune response and increases the release of growth hormone and insulin. In a study, Gambardella et al. determined the effect of chronic l-arginine supplements on the physical fitness of water polo players. The results showed that l-arginine did not change BMI, muscle strength and maximum speed in 200 meters after 4 weeks. However, L-arginine was effective in improving oxidative metabolism in professional water polo players through the mechanism of increasing mitochondrial function (50).

Considering the conflicting results regarding the effects of Arginine supplementation on muscle volume and lean mass as well as plyometric exercises on improving performance, the present study has done by determining the effect of plyometric exercise with arginine supplementation on some physical fitness factors including aerobic and anaerobic capacity, muscle strength and endurance and fat percentage which are important factors to prevent common injuries of beach soccer players.

Material and methods

Subjects

In this pre-experimental research, according to similar researches, 20 male beach soccer athletes aged 18-30 years with at least 2 years of experience in this sport were randomly assigned in two training groups of Plyometrics with arginine supplement (n=10) and plyometric exercise with placebo (n=10).

Testing

First, the factors of age, height, weight, aerobic and anaerobic capacity, muscle strength and endurance, and fat percentage of the subjects were evaluated.

Anaerobic capacity was measured by the Rast test. For this purpose, the subjects ran the distance of 35 meters which was marked with cones, 6 times at full speed, while they rested for 10 seconds between each stage of running, and the running time was recorded for them, and then using the existing formulas, Maximum, minimum and average power and fatigue index were calculated (51).

Aerobic capacity was estimated using Cooper's 12-minute running test by recording the distance covered.

Chest press and front thigh press tests were used to evaluate strength. In performing these tests, the subject chose a weight which he could perform 4 to 6 movements and after performing, the 1RM was obtained through the corresponding formula (52).

To evaluate the endurance of the muscles of the central region, the subjects performed the sit up test for 1 minute, and the number of movements considered as their record (53).

To measure the percentage of body fat, the thickness of the subcutaneous fat was measured by a caliper at three points of the chest, thigh, and abdomen. All measurements were performed on the right side of the body. Fat percentage was calculated using the Jackson-Pollack formula (54).

Then, the first training group received plyometric exercises along with daily consumption of 500 mg of arginine in the form of capsules before training. According to the purpose of the research and the weight of the subjects, we used 500 mg capsules on average. In the second group, plyometric exercises were applied along with placebo (55). The plyometric training protocol was performed three sessions a week for 8 weeks, including 6 rounds of jumping, each set including 6 consecutive jumps over the obstacle with the maximum height and the minimum contact time of the feet with the ground. The distance between the obstacles was one meter and the height of the box was 40 cm. The pause between each rebound was about five seconds and the rest between sets was three minutes. Meanwhile, the number of sets increased from 6 sets in the first week to 12 sets in the last two weeks.

At the end of the research period, physical fitness factors including aerobic and anaerobic capacity, muscle strength and endurance, and fat percentage were reevaluated.

Statistical Analysis

After calculating the mean and standard deviations, the Shapiro-Wilk test was used to determine the normality of the data distribution, and the correlated t test was used to determine the intra-group changes, and the analysis of covariance test was used to compare between groups. Results obtained analyzed using the software SPSS version 26.

Results

The results of descriptive statistics of each group, including age, height, weight, body mass index (BMI) and sports history of subjects are summarized in Table 1. The results of the independent t-test in two groups show that the groups are homogenous in terms of the mentioned factors (P<0.05).

Table 1. Descriptive statistics of the subjects' anthropometric characteristics

variable	group	number	Standard deviation ± mean	p
Age (years)	plyometric	10	23/90 ± 4/62	0/52
	Plyometric+ Arginine supp.	10	25/20 ± 4/34	
Height (m)	plyometric	10	1/79 ± 0/03	0/36
	Plyometric+ Arginine supp.	10	1/78 ± 0/04	
Weight (kg)	plyometric	10	77/70 ± 4/34	0/49
	Plyometric+ Arginine supp.	10	76/10 ± 5/70	
BMI ($kg/m^{2)}$	plyometric	10	24/06 ± 1/17	0/87

	Plyometric+ Arginine supp.	10	23/99 ± 1/01	
Sports history (years)	plyometric	10	5/80 ±1/54	0/49
	Plyometric+ Arginine supp.	10	6/30 ± 1/63	

Then the Shapiro-Wilk test was performed, which showed the normality of data distribution in the studied variables (P<0.05).

Then correlated t-test was used to check the difference in pre-test and post-test in two groups separately (Table 2).

Table 2. Correlated t-test results of differences in aerobic power, anaerobic power factors (minimum, maximum, mean power and fatigue index), muscle strength (chest press and front leg press) and endurance, and fat percentage in subjects before and after exercise

group	plyometric				Plyometric+ Arginine supp.			
	Pre-test	Post-test	T	P	Pre-test	Post-test	T	P
Aerobic power (sec)	135/46 3110/00 ±	± 123/08 3177/70	-4/68	0/001**	± 179/53 3055/70	80/61 ± 3219/00	-4/36	0/002**
Min. Anaerobic power (watt/sec)	60/16 277/27 ±	± 61/25 269/34	3/89	0/004**	53/51 262/10 ±	52/28 246/44 ±	7/61	0/001**
Max. Anaerobic power (watt/sec)	± 173/67 497/14	± 170/38 486/48	11/13	0/001**	± 187/55 561/66	± 188/41 546/03	9/11	0/001**
mean Anaerobic power (watt/sec)	± 36/43 230/92	± 37/93 221/93	6/54	0/001**	36/82 227/78 ±	37/38 215/75 ±	8/61	0/001**
Fatigue index (watt/sec)	± 3/08 5/51	± 2/77 5/15	2/92	0/01**	± 3/37 5/80	2/92 ± 5/00	3/94	0/003**
chest press (kg)	± 5/64 85/60	± 5/24 89/20	-13/50	0/001**	± 7/07 83/60	± 6/50 87/90	-7/20	0/001**
front leg press (kg)	± 8/29 77/90	± 7/34 81/70	-6/21	0/001**	±3/89 74/60	± 3/88 83/00	-6/41	0/001**
Muscle endurance (n)	± 3/17 58/10	± 2/71 59/40	-3/88	0/004**	± 3/68 56/70	± 2/45 58/70	-3/87	0/004**
fat percentage	± 2/34 24/95	± 2/10 24/41	5/46	0/001**	± 2/64 23/94	± 2/52 23/19	7/44	0/001**

** Significance at the 0.01 level

The results of the correlated t-test show that the application of plyometric exercises and plyometric exercises with arginine supplementation in the training groups had a significant effect on improving aerobic capacity, anaerobic capacity, muscle strength, muscle endurance and reducing fat percentage.

After checking the homogeneity of the variance of the pre- and post-test groups for all variables by the Levan’s test, analysis of covariances was performed to examine the effect of the independent variable on the post-test (Table 3).

Table 3. The results of covariance analysis of the effect of independent and predictor variables on aerobic power, anaerobic power (minimum, maximum and mean power and fatigue index), muscle strength (chest press and front leg press), muscle endurance and fat percentage after the test

variable	**Test stage**	**group**	**mean**	F	df	P	Eta squared
Aerobic power	Post-test	plyometric	3162/63	7/69	1	0/01**	0/31
	Post-test	Plyometric+ Arginine supp.	3234/06				
Min. Anaerobic power	Post-test	plyometric	261//80	6/78	1	0/01**	0/28
	Post-test	Plyometric+ Arginine supp.	253//98				
Max. Anaerobic power	Post-test	plyometric	518//78	6/07	1	0/02*	0/26
	Post-test	Plyometric+ Arginine supp.	513//73				
mean Anaerobic power	Post-test	plyometric	220//35	2/24	1	0/15	0/11
	Post-test	Plyometric+ Arginine supp.	217/33				
Fatigue index	Post-test	plyometric	5/28	6/52	1	0/02*	0/27
	Post-test	Plyometric+ Arginine supp.	4/87				
chest press	Post-test	plyometric	89/21	0/24	1	0/62	0/01
	Post-test	Plyometric+ Arginine supp.	87/88				
front leg press	Post-test	plyometric	82/00	0/66	1	0/42	0/03
	Post-test	Plyometric+ Arginine supp.	82/69				
Muscle endurance	Post-test	plyometric	58/90	0/42	1	0/52	0/02
	Post-test	Plyometric+ Arginine supp.	59/19				
fat percentage	Post-test	plyometric	23/95	6/07	1	0/02*	0/26
	Post-test	Plyometric+ Arginine supp.	23/65				

¥ Adjusted to pre-test values
** Significance at the 0.01 level
* Significance at the 0.05 level

The results of the analysis of covariance test showed that after controlling the effect of the pre-test, there is a significant difference in the results of aerobic power and anaerobic power (except the average power) and fat percentage in the post-test between the two training groups (=0.01). P), In other words, the effect of plyometric training with arginine supplement on aerobic power, minimum and maximum power, fatigue index and fat percentage were greater than plyometric training alone. There is no significant difference between the effect of plyometric training with arginine supplement on muscle strength in chest press and front leg press and muscle endurance with plyometric training alone.

Discussion

The results of the findings showed that both plyometric training programs with and without arginine supplementation had a significant effect on improving aerobic power (P=0.002, P=0.001), anaerobic power (P=0.001), muscle strength (P=0.001), muscle endurance (P=0.004) and fat percentage (P=0.001). Also, the results of comparing the effect of two training programs show that there is a significant difference between the two training programs in the variables of aerobic power (P=0.01), anaerobic power (P=0.01) and fat percentage (P=0.02). The results are aligned with the results of studies by Biswas and Ghosh, which pointed out the effect of plyometric exercises in dry and water environments on the aerobic capacity of athletes (56), Mor et al. who pointed out the effect of arginine supplementation on improving anaerobic power and recovery of athletes (57) and Viribay et al., who pointed out the effect of arginine supplementation on aerobic and anaerobic power based on energy metabolism (55).

In the context of how plyometric exercises affect aerobic power, the characteristics of these exercises should be mentioned. Plyometric training consists of high-intensity movements performed by rapidly lengthening and then shortening the muscle. Significant responses to repeated jumps lead to increased oxygen consumption and utilization, preservation of neuromuscular function, intermuscular coordination patterns, muscle buffering capacity, and phosphocreatine recovery (58). Long-term muscle activity is influenced by several aerobic factors such as maximal oxygen consumption, and its utilization, energy production, availability and constant energy supply in working muscles, and running economy (59). It also depends more on neuromuscular characteristics, i.e. reactive strength index (RSI), muscle strength and stiffness (56). Indeed, running economy as an important determinant of aerobic capacity can be influenced by neuromuscular activation with stimulus intensity (59). Therefore, the total energy cost of running is determined by the sum of aerobic and anaerobic metabolism (neuromuscular factors (60). So, for endurance athletes, training strategies are the most important thing to target to increase aerobic and neuromuscular factors related to aerobic performance (59). In addition, the improvement of running performance after performing plyometric exercises has been attributed to the increase of muscle-tendon stiffness, and the improvement of running economy is determined by the reduction of oxygen consumption at running speed (61). Therefore, plyometric training is expected to improve running performance by increasing muscle-tendon stiffness (62). In case of injury prevention, lower aerobic capacity has revealed injury risk within the military(63). These findings are likely explained by the fact that Soldiers or athletes with less physical fitness are prone to fatigue earlier and cannot tolerate high training volume/intensity, resulting in alterations in the neuromuscular control and diminished ability to achieve functional joint stability (64).

In the context of the effect of plyometric exercises on anaerobic power, we can also mention the characteristics of this training program. If we consider power as a combination of strength and speed, there are two ways to increase it: first, increasing the force produced by the muscle, and then reducing the time it takes to produce force. Generally, to increase muscle strength, resistance exercises are used alone, if it is suggested to increase muscle strength at the same time and especially to reduce production time, speed strength or plyometric exercises are suggested.

Moreover, regarding the effect of plyometric exercises with arginine supplement compared to plyometric exercises with placebo, we can mention the effect of arginine supplement. In this context, it was stated that amino acids are one of the most common food supplements that are used by athletes to improve sports performance in aerobic and anaerobic conditions (65). L-arginine may play a key role in the cardiac performance of athletes. Arginine is a precursor of nitric oxide (NO) and NO causes vasodilatory effects, increases blood flow to muscles and increases the secretion of some hormones such as insulin and human growth hormone (66, 67). On the other hand, L-arginine can improve athletic performance by increasing protein synthesis and reducing muscle fiber damage (68), which consuming this supplement could be an additional injury preventive way along with exercises.

In general, based on the mentioned cases, the use of plyometric exercises, especially in addition to arginine supplement, is recommended for athletes to improve aerobic and anaerobic endurance and consequently prevent injuries to the central and lower parts of the body.

The results of the present study, which show the effect of both training programs on improving the strength and muscular endurance of beach soccer athletes is aligned with the results of some of the studies who pointed out the effect of plyometric exercises on improving muscular endurance (69), On improving strength and endurance (70), on improving the strength of lower limb muscles of wrestlers (71) and on improving the muscular strength of football players (72). The findings of the present study can be attributed to the central and peripheral neuromuscular adaptation caused by plyometric training and increased proprioceptive and motor awareness. It has been suggested that the eccentric contraction phase of plyometric exercises causes repetitive mechanoreceptor stimulation and rapid changes in the length and tension of muscle tendon structures. These effects may reduce the inhibitory effect of the Golgi tendon organs and increase the sensitivity of the muscle spindle, especially the antigravity muscles. In addition, it may help the central nervous system with awareness of joint position and movement (73). Neurological adaptations resulting from plyometric training and proprioceptive correction may also contribute to increased body weight support. In addition, plyometric training is thought to improve muscle elasticity, increase functional stability, and increase muscle and joint stiffness, which may reduce longitudinal contraction in lower limb and trunk muscles and help transfer force generated by body weight (74). On the other hand, the increase in strength and endurance after plyometric training is most likely related to the improvement of motor unit recruitment pattern and increase in motor neuron excitability, better contraction and increase in muscle synergistic activities (75). In this regard, a meta-analysis has reported the effectiveness of plyometric training for increasing muscle strength in adults and pre-puberty people (76).

The results of the present study did not show any difference between the effect of plyometric exercises with and without arginine supplementation on muscle strength and endurance. In this regard, Alvarez et al showed that the use of arginine supplement leads to an increase in blood flow to the muscle, but it was not associated with an improvement in muscle strength (77). Also, Greer et al pointed out the lack of effect of arginine supplementation on improving muscle endurance (78). According to the fact that strength deficits have shown to be prospective risk factors for overuse knee injuries, knee joint trauma, and muscle strains of the thigh (79, 80), and trunk strength determinants were predictors of core and lower extremity sprains and strains and low back injuries in collegiate athlete populations (81, 82), and according to the fact that plyometric exercises could increase muscle strength and endurance, use of these exercises is recommended for athletes to improve them and consequently prevent injuries to the central and lower parts of the body.

Although the results of some studies on the effect of arginine supplement showed that this had no effect on body fat mass (83, 84), In a research, the effect of plyometric exercises on reducing the body fat mass of handball players has been mentioned (85). Canli and colleagues also mentioned the effect of strength training and plyometrics on body mass index (86), And Daneshjoo and Raeisi also pointed out the effect of plyometric exercises on reducing the body fat percentage of parkour athletes (87). These differences could be related to different methods of doing exercises. According to the results obtained in the current research on the effect of arginine supplementation on fat percentage, it seems that the decrease in fat percentage during the program is due to the effects of plyometric exercises on improving muscle strength. The risk factors that are associated with ACL injury in both male and female athletes are including an increase in body weight and specially for female athletes, increasing body mass index (88). Also an increase in time missed due to injury results in an increase in body fat (89). In addition, young Elite Soccer Players with increased BMI were at a higher risk of injury (90).

According to the results and previous studies, using two types of plyometric exercises, with and without using Arginine supplementation could be useful to prevent sports related injuries specially ankle and knee sprains and groin strain which are prevalent among soccer players of all types, by different explained mechanisms (affecting aerobic and anaerobic powers, muscle strength and endurance, and body fat). Based on the results, the use of both types of training programs, especially plyometric exercises with arginine supplementation, is recommended for beach soccer athletes to have best function and thus prevent sports injuries.

Conclusion

Considering the effect of plyometric exercises, especially in combination with arginine supplement, on aerobic and anaerobic power, muscle strength and endurance, and body fat percentage, using this training program for soccer athletes, especially beach soccer, is suggested to coaches. In addition, beach soccer is a relatively new sport for which no national professional leagues exist in many countries. Thus, doing future studies investigating other characteristics of beach soccer players is suggested. In order to expand the scope of the research, it is suggested to compare the effect of plyometric exercises with and without arginine supplementation on improving strength, endurance, aerobic capacity, and anaerobic capacity and fat percentage of athletes in other sports.

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