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Effect of Plyometric Training Conducted in Aquatic Medium on Speed and Explosive Strength of the Athletes

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ABSTRACT

Background: Plyometric training (PT) are performed in different hard surfaces like dry land, hard court or grassy turf which is at the same time susceptible to muscle and joint injury of the lower limbs. To avoid this risk Aqua-based training gradually has become popular to the trainers. Therefore, in the present study the PT were conducted in an aquatic medium. **Objective:** The purpose of the present study was to investigate the effect of Aquatic plyometric training on speed and explosive leg strength ability of the young Indian athletes. **Method:** This study was quasi-experimental in nature. Twenty-four (N = 24) athletes aged between 14-16 years were selected. They were equally grouped into two: i) *Aquatic Plyometric Training Group* (APTG, N=12), and ii) *Control Group* (CG, N=12). Both the groups were involved in regular physical activity as usual in their academy which was not under the control of the researchers, however, in addition to that APTG underwent an aqua-based Plyometric training for fourteen weeks. The dependent variables were speed and explosive leg strength. Baseline (pre) and post intervention mean values for APTG and CG were analyzed through ANCOVA. The F-values were tested at $p<0.05$ level of significance. **Results:** The APTG improved significantly with respect to the CG in speed ($F = 70.890$; $p < 0.00001$) and explosive leg strength ($F = 32.553$; $p < 0.00001$). **Conclusion:** Aquatic Plyometric Training was found as an effective training means for the development of speed and explosive leg strength of the athletes belongs to the age group of 14-16 years.

Key words: Jump Training, Stretch-Shortening Exercise, Sprinting Speed, Muscle Strength, Explosive Leg Strength

INTRODUCTION

Plyometric training (PT) is a special type of training that is frequently used in both team and individual sports to improve human performance (Davies et al., 2015; Sammoud et al., 2019). Explosive muscular extension and contraction are the hallmark of PT (Davies et al., 2015; Ramírez-delaCruz et al., 2022). As training means PT involves different high impact exercises like jumping; bounding, and others that targets to maximize the stretch reflex of the muscles. The ultimate target of this training is to produce maximum muscular force instantly with highest rapidity, that improves the anaerobic task faster as a result best possible performance comes from the athletes (Branquinho et al., 2022; Moran et al., 2018). Three steps make up these particular exercises: the pre-activation (eccentric phase), amortization (isometric phase), and shortening (concentric phase) (Chmielewski et al., 2006; Ghosh & Biswas, 2020b). The stretch-shortening cycle (SSC) (Markovic & Mikulic, 2010) is the rapid change from the eccentric to the concentric phase of the movement. The golgi tendon organs are stretched more during the eccentric pre-activation phase of PT than during ordinary strength training, which causes a larger suppression of their protective role and an increase in concentric power output (Davies et al., 2015; Lum et al., 2019). Improvements in muscle strength, dynamic stability, and neuromuscular control, as well as an increase in contraction speed and joint stiffness, are all linked to these changes (Markovic & Mikulic, 2010). Numerous physical attributes, including sprint speed (Hoef et al., 2020), agility (Villarreal et al., 2008), strength and jump height (Oxfeldt et al., 2019), running economy(Lum et al., 2019), endurance (Hoef et al., 2020), and motor performance skills (Sortwell et al., 2021) have been proven to be improved by PT. Plyometric training has become so popular that the coaches and trainers implement this training means on the advanced athletes with a view to improve the concentric and eccentric muscle action for the execution of maximum explosive force instantly resulting in improved explosive power output, improved speed and acceleration during dynamic movements (Coetzee, 2007).

Aquatic training has become an essential training method in recent years for improving specific physiological characteristics (Miller M. et al., 2007; Peyré-Tartaruga et al.,

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2009). Because water offers more resistance than land does, performing plyometric exercises in it can help improve force output more than doing them on land (Colado et al., 2010). Aquatic plyometric training is a type of workout that can improve performance during a competitive season for a power-based sport (MillerM. G. et al., 2002; Robinson et al., 2004).Athletes may benefit in a number of ways from plyometric exercises done in the water. Because of the buoyant properties of water, which support the athlete's body as it moves downward and prevent upward movement, water acts as a counterforce to gravity(Biswas & Ghosh, 2022a, 2022c; Suomi & Koceja, 2000).

Acceleration, speed, horizontal and vertical leg explosive power, dynamic leg explosive power etc are the essential components of sports performance(Ghosh & Bhowmick, 2018). All these components are associated with explosive power(Ghosh et al., 2022). Power combines strength and speed (Farentinos & Radcliffe, 1999). Locomotor-ability is one of the important factors for execution of any type of sport skill where explosive type of muscular force/power generation is needed (Baechle & Earle, 2008; Sáez Sáez de Villarreal et al., 2011).In all activities and sports, strength and speed are essential(Ghosh & Bhowmick, 2018). Each participant must have explosive force, quick reactions, and acceleration speed. The frequency of excitation acting in a given time unit equals this force (Biswas & Ghosh, 2022c; Senthil Kumar, 2016). Plyometric workouts are believed to increase muscular force and power because the elastic energy is held throughout the eccentric period. When a concentric contraction occurs right after, the overall force produced is enhanced, resulting in a stronger and higher jump (Baechle & Earle, 2008a; Biswas & Ghosh, 2019; Ghosh & Biswas, 2020)

In the world of athletics, the trainers always favor using a training environment that is friendly to athletes in order to improve locomotor skills with a lower risk of damage (Fabricius, 2011). The musculoskeletal junction, particularly the muscle-tendon complex and the ligaments of different joints, is consistently stressed during prolonged physical activity on a dry surface, increasing the risk of injury for the athlete (Biswas & Ghosh, 2019, 2022a, Ghosh & Biswas, 2020; Suomi & Koceja, 2000). These injuries hinder the athlete's ongoing growth and reduce the length of their career. Athletes who practice in aquatic environments are shielded from these risks and are able to maintain their fitness even after exhausting training sessions. Aqua-Plyometric Training, or plyometric exercises in the water, has various advantages for athletes. The buoyancy of the water makes it a force that opposes gravity (Biswas & Ghosh, 2019, 2022a, 2022b, 2022c; Ghosh & Biswas, 2020; M. G. Miller et al., 2001; Suomi & Koceja, 2000). When practicing aquatic plyometric training, the water provides buoyancy and lessens stress on the limbs from weight, relieving pressure on the musculoskeletal system. In comparison to moving on land or other surfaces, moving in the water requires more muscular activity due to its viscosity and friction (Arazi & Asadi, 2011). The athlete is less likely to sustain an injury owing to the water's buoyancy, which reduces the force applied to the body when they land.

Aquatic exercise gives trainers the freedom to use a higher training intensity during movement execution with more repetitions in a safe, pleasant, and modified training environment that is friendly to athletes (Soultanakis, 2016). Exercises along the vertical direction of the water surface increase turbulence, which maximizes the resistance from water drag force and helps coaches strengthen the active muscles in reduced weight-bearing conditions (Fabricius, 2011), allowing athletes to avoid injury(Triplett et al., 2009). This is due to the buoyancy of the water, which imposes less impact force. Because hydrodynamic training has a similar training effect to land training—and occasionally even a better effect—and a lower risk of injury, coaches and trainers might choose this training as a preferable alternative to land-based training (Sporri et al., 2018; Turner & Jeffreys, 2010; Wilson et al., 1994). Because more muscles and joints are used simultaneously during aquatic training, the energy expenditure is larger than it is during other types of training, which helps trainers make quick improvements. Since water is 800 times denser than air (Pohl & Mcnaughton, 2003), moving through it is substantially more difficult than doing so on land. Jumping horizontally in the water demands more effort to overcome water resistance which aids in the development of stronger muscles (Irvin & Johnson, 2000).

Consequently, the purpose of the current study was to determine the impact of plyometric training on the athlete's locomotor skills when it was done in an aquatic environment. Sports scientists are constantly engaged in identifying how plyometric training in aquatic environments influences the development of locomotor skills, despite the fact that the effects of plyometric training on the development of speed, explosive strength, and power in hard surfaces have long been known (Addie et al., 2022). Sometimes uniformity of identical training for months long seems monotonous to the athletes and a changed environment with ample advantages reenergizes them to be involved in the training with a positive mind set (Tao, 2018). Aquatic environment gives such an advantage with reduced ground impact force for the jump type training. In reference to the previous studies in the area of rehabilitation from injury, aquatic mediums were used for the development of motor components (Biswas & Ghosh, 2019, 2022a). With a view to provide a supportive training environment to the young athletes the researchers selected aquatic plyometric training to prevent the joints of the lower limb of the athletes from high ground impact force for land plyometric. Researchers were interested in developing the strength and power of the young athletes at the same time they wanted to prevent additional jerking on the joints (Ghosh & Biswas, 2020; Suomi & Koceja, 2000). It is also known that the aquatic medium reduces the ground impact forces due to its buoyant properties, therefore, reduces unexpected injury threats and appears advantageous too to the athletes (Soultanakis, 2016). Therefore, it was hypothesized that aqua-based plyometric training might be a useful training method for the developments of locomotor skill i.e. speed and explosive leg strength of the athletes. The aim of the current study was to advance our understanding in this area. In light of this, the purpose of this study was to ascertain the effect of aquatic-based plyometric training on young athletes' locomotor abilities, namely their speed and explosive leg strength.

MATERIALS AND METHODS

Study Design

The present study was a quasi-experimental research work which was designed with a view to determine how aquatic plyometric exercises affected locomotor functions speed and explosive leg strength of the young Indian athletes. Prior to the selection of the subjects few inclusion criteria [i. Age: 14-16 years, ii. Sex: Male, iii. Training Age >4 Years& iv. All the subjects were middle distance Runners] and few exclusion criteria [i. Chronic ailments, ii. Major Injury, iii.16<Age<14 Years, iv. Sex: Female, and v. Involved in other controlled training program] were imposed on the initially shorted athletes and those athletes were finalized as participants for the present study who passed the medical test conducted for the study by an expert medical practitioner and also after getting the consent form (participants copy as well as guardians copy) submitted timely to the researchers. In the current study, *speed* and *explosive leg strength* were considered as dependent variables (DV) and measured through a 50m sprint run test (SRT) and standing broad jump (SBJ)test respectively. In the present study aquatic plyometric training was intervened on the APTG for fourteen weeks within a specially designed water reservoir with water up to waist height. Pre-treatment and Post-treatment data on DV were collected for APTG as well CG following the standard guidelines of the tests. All the collected data were analyzed through standard statistical procedures. The entire experimental design is shown in Figure 1.The study was placed before the Departmental Research Committee (DRC) of the University of Kalyani and after receiv-

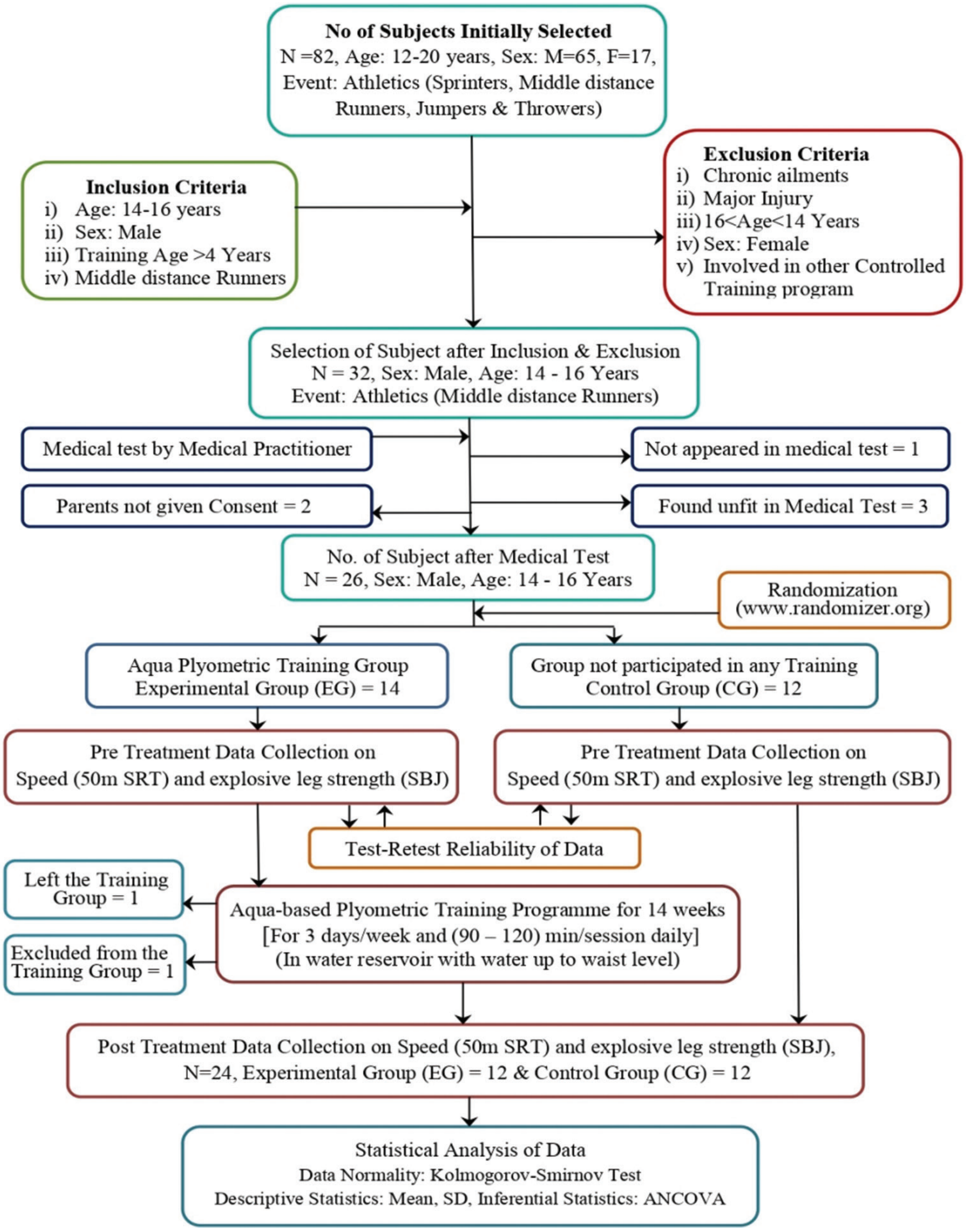

Figure 1. Experimental design

ing the clearance from the research committee the work started.

Participants

The sample size for the present study was calculated by using G*Power V3.1.9.4 software(Ghosh et al., 2022; Sortwell et al., 2021). A priori power analysis was performed through the said software for ANCOVA to compute the required sample size for the group in a given condition of α = 0.05, Power = 0.80, Effect size = 0.60(Ghosh et al., 2022; Munger et al., 2022), numerator df =1, and Number of groups =2 that determined a total sample size of twenty-four (N =24) with Denominator df = 21 and the Critical value of F =4.32479. Therefore, power analysis in the above-given conditions suggested that 12 subjects for each group would be needed for the study. Considering a maximum 15% drop-out rate or attrition rate 8 subjects were added with the total sample size. Accordingly, on the basis of the software (G*Power V3.1.9.4).

Recommendation and inclusion & exclusion criteria, thirty two (N=32) middle distance male track athletes were selected from a population of eighty two athletes and after exclusion sample size was reduced to twenty-four. They were split into two groups through the process of randomization (by www.randomizer.org): 1) Control Group (CG, N = 12) and 2) Experimental Group (APTG, N = 12) also assigned as an Aqua-based Plyometric Training Group (APTG). In Table 1 the descriptive data i.e. no. of subjects in each group, total no. of subjects, age (years), height (cm.) and weight (Kg.) of the subjects belonging to the APTG and CG have been presented.

Training Protocol

In order to encourage and inspire the participants to remain active and serious during the training sessions, an orientation program was organized with all subjects and their parents, where the purpose of the present research work, its importance, and full procedures to be followed for the study were discussed clearly. Full liberty was given to all the participants to quit from the study anytime if they faced any physical problem due to the training schedule. Baseline (pre-test) data were collected for both APTG& CG in speed and explosive strength in consecutive two days where test-retest reliability of data was also judged. After the aquatic plyometricic training for fourteen weeks long was started to intervene on the APTG. The subjects of the APTG were engaged three days (Tuesday, Thursday, Saturday) in a week and 90-120 minutes long sessions in a day in the afternoon hours from 4.00h to 6.00h (Biswas & Ghosh, 2019, 2022a, 2022b; M. G. Miller et al., 2001).Every day, prior to the start of the aquatic plyometric training, the athletes in the APTG had received rigorous warm-up for 15 minutes long. In the warm-up period the subjects were instructed to perform few general exercises (low intensity running, jogging with different arm movements, freehand exercises, short sprint, stretching etc.) and few specific exercises (exercises with light equipments, short jump, hopping, squat, bending exercises, high knee, hammering and hyper stretching exercises etc.) for stimulating the muscles to be prepared properly for plyometric training. Again after the completion of the everyday training program they had received proper cool-down exercises(recreational games with low intensity movements, lead-up games, partner-wise stretching exercises, water polo and low intensity underwater stretching exercises) too for fifteen minutes to recover faster from the training load. In an artificial water reservoir with water up to the waist level, seven exercises— namely the single-leg hop (both legs), upward jump and squat, double leg bounding, split jump, tuck jump, box jump, and depth jump—were successively set up for the athletes. Both the volume and the intensity of exercises gradually increased. Between the repetitions of exercise and between each set of exercises, appropriate passive recovery periods of two to three minutes were given (Arazi & Asadi, 2011; Ghosh & Medya, 2014; M. Miller et al., 2007; M. G. Miller et al., 2002). In Table 2, the distributions of the timing of the training schedule and in Table 2 detail volume of the contents of the training protocol have been presented for clear understanding. Table 3 contains a thorough description of the aqua-based plyometric training strategy. However, the control group was not a part of the treatment plan. During the training session members in every group were permitted to do their usual activities as it was not under the control of the researchers. For both the groups, pre- and post-training data were collected in order to assess the athletes' speed and explosive strength. The following tables (Table 2- Table 4) describe the weekly training program, its volume, intensity rest periods with warm-up & cooling down periods.

Adherence to Training & Adverse Effect

In all the training sessions throughout the training period the attendance of the athletes were maintained in a register by the researchers. While calculating the adherence to the training protocol, it was observed that the APTG attended 39.67 ± 0.98 sessions (94.44%), out of a total 42 sessions conducted in the training program. Every participant in the

Table 1. Mean and SD of age, height and weight for the subjects of the two groups in baseline (pre-experimental) condition

Sl. No.	Name of the Group	No. Of Subjects	Age (years)	Height (cm.)	Weight (Kg.)
			Mean±S.D	Mean±S.D	Mean±S.D
1	APTG	12	15.67±1.56	155.92±5.50	48.54±5.40
2	CG	12	14.75±1.54	154.33±4.91	45.40±7.39

Total no. of Subjects: (N) =24

Table 2. Weekly time distribution of the training protocol

Training Weeks	Warm-Up Periods	Training Volume (time)	Cooling Down Periods	Total Recovery Periods	Total Training Periods	Training Intensity
I to II	15m	25m	15m	40m	95m	Low
III to IV	15m	30m	15m	40m	100m	Low/Medium
V to VI	15m	30m	15m	40m	100m	Low/Medium
VII to VIII	15m	35m	15m	45m	110m	Low/Medium/High
IX to X	15m	35m	15m	45m	110m	Low/Medium/High
XI to XII	15m	40m	15m	45m	115m	Low/Medium/High
XIII to XIV	15m	45m	15m	45m	120m	Medium/High

'm' indicates the unit of time in minutes

Table 3. Detail volume of the contents in the aqua-based plyometric training intervention

Contents	Volume
Duration of the entire study (Weeks)	16 weeks
Duration of intervention program (Weeks or days)	14 weeks or 98 days
Number of loading days	42
Number of training units	42
Weekly load volume (minutes)	285-360
Total load volume in entire training periods (minutes)	3390-5040
Total warm-up volume in the introduction part (minutes)	630
Total load volume in workout parts of the training (minutes)	1050-1890
Total volume of recovery during workout in training (minutes)	1660-1890
Total cooling down volume (minutes)	630
Intensity of training gradually increased (from – to)	Low – Medium - High

APTG attended at least 38 sessions (90.48%) of the total number required by the training program. No adverse events reported by the researchers during the training period.

Measurement Procedures and Calculations

The height and body weight of all the participants were measured by standard tools and techniques. The measurement procedure of two dependent variables for this study i.e. speed and explosive leg strength have briefly discussed below-

Speed

To calculate speed of the athletes, sprinting time in one hundredth of a second (s) for a 50m dash was measured manually through stop watch by considering the standard guidelines of the test (Fletcher & Anness, 2007). Equipment: measuring tape, smooth, grassy turf marked at 50 m, stopwatch, starting clapper, skilled timer, and scorer. Procedure: There was just one sprint allowed during the exam, which is 50 m long. A stopwatch provided data by recording the "time" in seconds it took to travel the distance. There were a maximum of two practice runs available. The subjects were encouraged to exert their utmost effort. The test was conducted using a standing start. Two trials were permitted. Data was considered to be the fastest time in one hundredth of a second. From this time data speed was calculated by the following equation-speed = distance/time = 50/time. The unit of speed is meter/second ($m.s^{-1}$).

Explosive leg strength

Explosive leg strength of the athletes was measured through standing broad jump (SBJ) test(Krishnan et al., 2017). Equipment: Measuring tape to measure jump distance, non-slip floor for takeoff with a line clearly marked and soft-landing area. Procedure: Proper warm-up was given to all the athletes prior to the test. The athlete placed his or her feet slightly apart behind a line (takeoff line) drawn on the ground. The forward motion was produced by swinging the arms and bending the knees, with a two foot take-off and landing. The subject made a long jump and landed on both feet without rolling backward. There were three opportunities. Rating: The distance from the takeoff line to the point of contact closest to the landing was measured (back of the heels). They recorded the longest distance they leapt as data from the top three trials in centimeters and converted it to meters.

Statistical Analysis

The reliability of the data was tested in the pre-test (baseline) condition by calculating the coefficient of correlation. The obtained data was evaluated, and the mean and standard deviation (calculated through excel spreadsheet) were displayed. Normality of the collected data was tested by Kolmogorov–Smirnov test (through *Social Science Statistics Software*) which confirmed that the data were distributed normally. Therefore, parametric inferential statistics analysis of covariance (ANCOVA through *VassarStats* software package) was used to compare the mean values of speed and explosive leg strength in baseline and post-intervention for both the groups (APTG& CG). Significance of the mean was tested at $p<.05$ level. To make the analysis more clear, % of change in speed and explosive leg strength from pre-test to post-test were calculated by using the following equation:

Table 4. Details of experimental protocol on aqua-based plyometric training

Training Week	Plyometric Drill	Training Intensity	Set × Repetitions	Training Volume (No. of exercise performed)
I & II Week	Side to side ankle hops	Low	2 × 15	96
	Standing long jump and reach	Low	2 × 10	
	Double leg hops	Low	3 × 10	
	Jump & squat	Low	2 × 8	
III & IV Week	Side to side ankle hops	Low	2 × 15	104
	Standing long jump and reach	Medium	2 × 10	
	Double leg hops	Medium	3 × 8	
	Jump & squat	low	3 × 10	
V & VI Week	Single leg hops (alternatively)	low	2 × 10	118
	Standing long jump	Medium	2 × 12	
	Double leg hops	Medium	3 × 10	
	Jump & squat	Medium	3 × 8	
VII & VIII Week	Single leg hops (alternatively)	Medium	2 × 6	120
	Standing long jump	Low	2 × 12	
	Double leg bounding	Medium	3 × 8	
	Jump & squat	High	3 × 8	
	Tuck jump	Medium	4 × 6	
IX & X Week	Single leg hops (alternatively)	High	2 × 6	106
	Double leg bounding	Medium	3 × 8	
	Jump & squat	High	3 × 6	
	Tuck jump	Medium	4 × 6	
	Split squat jump	Low	2 × 8	
XI & XII Week	Single leg hops (alternatively)	High	2 × 6	98
	Double leg bounding	High	3 × 6	
	Tuck jump	Medium	4 × 6	
	Split squat jump	Medium	2 × 8	
	Scissor jump	Low	2 × 8	
XIII & XIV Week	Double leg bounding	High	3 × 6	86
	Jump & squat	High	3 × 5	
	Tuck jump	High	4 × 5	
	Split squat jump	High	3 × 6	
	Scissor jump	Medium	3 × 5	

Δ% = [(Post Test Mean – Baseline Mean) × 100/Baseline Mean]

RESULTS

In Table 5, the baseline, post treatment and adjusted posttest Mean± SD values of speed for the APTG and CG were presented. The baseline F-value of speed was not found statistically significant [F=2.602; $df(1,22)_{0.05}$=4.303, p<0.12098]. It indicated that at baseline, the APTG and CG were properly equated as there was no significant difference found between these two groups. The post-treatment F-value of speed was found significant [F=10.896; $df(1,22)_{0.05}$=4.303, p<0.00326].In the post-treatment condition, it indicated that, in speed, there was a significant difference between the participants of APTG and CG. The adjusted post-test F-value of speed was found highly significant [F=70.890, $df(1,21)_{0.05}$=4.35, p<0.00001].It indicated that there was a significant improvement in speed of the subjects of APTG (Δ% = 3.46%) after the elimination (adjustment) of the effect of intervening factors as usually observed over CG (Δ% = -0.16%). Therefore, aqua-based plyometric training was found very effective for the development of speed of the athletes.

In Table 6, the baseline, post-treatment and adjusted post-test Mean± SD values of explosive leg strength for the APTG and CG were presented. The baseline F-value of explosive leg strength was not found statistically significant [F=0.189; $df(1,22)_{0.05}$=4.303, p<0.66799]. It indicated that at baseline, the APTG and CG were exactly equated as there were no

Table 5. Mean, SD and ANCOVA of speed between APTG (EG) and CG in baseline, post treatment and adjusted post test

Name of the variables& Test	Testing Condition	EG	CG	Source of variance	Sum of squares	df	Mean squares	F-Value	*p*-Value
Speed (m.s.$^{-1}$) (50m SRT)	Baseline Mean±SD	6.64±0.30	6.43±0.34	Between	0.27	1	0.270	2.602	0.12098
				Within	2.00	22	0.090		
	Post Treatment Mean±SD	6.87±0.30	6.42±0.36	Between	1.20	1	1.200	**10.896***	0.00326
				Within	2.41	22	0.109		
	Adjusted post test Mean	6.76	6.53	Between	0.29	1	0.290	**70.890***	0.00001
				Within	0.09	21	0.004		
Percentage of improvement (Δ%)		3.46%	- 0.16%						

*Sign indicates the value statistically significant, The table values required for significance at 0.05 level with df (1,22) and (1,21) were 4.30 and 4.35 respectively, SRT=Sprint Run Test, m.s-1=meter/second=meter per second=unit of speed EG=Experimental Group, CG=Control Group, Δ% = [(Post Test Mean – Baseline Mean) × 100/Baseline Mean]

Table 6. Mean, SD and ANCOVA of explosive leg strength between EG (APTG) and CG in baseline, post treatment and adjusted post test

Name of the variables & Test	Testing Condition	EG	CG	Source of variance	Sum of squares	df	Mean squares	F-Value	*p*-Value
Explosive Leg Strength (m) (SBJ)	Baseline Mean±SD	2.21±0.16	2.17±0.20	Between	0.01	1	0.010	0.189	0.66799
				Within	1.00	22	0.045		
	Post Treatment Mean±SD	2.39±0.09	2.24±0.17	Between	0.15	1	0.150	**7.880***	0.01027
				Within	0.42	22	0.019		
	Adjusted post test Mean	2.38	2.25	Between	0.11	1	0.110	**32.553***	0.00001
				Within	0.07	21	0.003		
Percentage of improvement (Δ%)		8.15%	3.23%						

*Sign indicates the value statistically significant, The table values required for significance at 0.05 level with df (1,22) and (1,21) were 4.30 and 4.35 respectively. SBJ=Standing Broad Jump, m=meter. EG=Experimental Group, CG=Control Group, Δ% = [(Post Test Mean – Baseline Mean) × 100/Baseline Mean]

significant differences found between these two groups in explosive leg strength.

The post-treatment F-value of explosive leg strength was found significant [F=7.880; df$(1,22)_{0.05}$=4.303, p<0.01027]. In the post-treatment condition, it indicated that, in explosive leg strength, there was a significant difference between the participants of APTG and CG. The adjusted post-test F-value of explosive leg strength was found highly significant [F=32.553, df $(1,21)_{0.05}$=4.35, p<0.00001]. It indicated that there was a significant improvement in explosive leg strength between the pre and posttest condition of the subjects of APTG (Δ% = 8.15%) after the elimination (adjustment) of the effect of intervening factors as usually observed over CG (Δ% = 3.23%) from pre to post training condition. Therefore, aqua-based plyometric training was also found very effective for the development of explosive leg strength of the athletes.

DISCUSSION

The purpose of this study was to find out the effect of plyometric training conducted in aquatic medium on speed and explosive strength of the athletes. The result of the present study on speed indicated that the APTG brought about significant improvement in comparison with the CG after fourteen weeks of aquatic plyometric training programs. In all types of plyometric training, the utilization of stretch-shortening cycles of the flexor and extensor muscle groups has been demonstrated to have a strong link with short sprint times, which has led to the suggestion in several studies that plyometric training may improve speed (Baechle & Earle, 2008; Chu, 1998; Hennessy & Kilty, 2001; M. G. Miller et al., 2002; Robinson et al., 2004). Three distinct phases make up the stretch-shortening cycle (SSC), namely the eccentric phase, amortization phase, and concentrative phase. The interval between the eccentric and concentric phases, or the moment the feet make contact with the ground, is referred to as the amortization phase. It is the phase that is most important for generating the most force. If the amortization period lasts too long, the energy saved during the eccentric phase will be wasted as heat, which prevents the stretch reflex from activating more muscles during the ensuing concentric phase (Baechle & Earle, 2008; Kobak et al., 2015). Plyometric training is regarded as a very effective training method for activities that call for explosive and powerful movements in a short amount of time because, according to a few studies, it increases the muscles' ability to exert their maximum force instantly, or in a very short period of time (Baechle & Earle, 2008; Kobak et al., 2015). It may have occurred because the aquatic plyometric training involves many jumps and falls from various heights that need the muscles' capacity to stretch explosively and quickly transition from eccentric to concentric contraction (Arazi & Asadi, 2011; Gehri et al., 1998).

The result of the study on explosive leg strength in terms of horizontal jump indicated that the improved significantly in comparison with the CG after fourteen weeks of aquatic plyometric training programs. Several studies have suggested that plyometric training consists of jumping, bounding and hopping exercises improved the ability of explosive force production by the muscles thus it is considered as an useful training means for the said purpose (Baechle & Earle, 2008; Kobak et al., 2015). It is due to the fact that the concentric phase of movement in stretch-shortening cycle (SSC) the power output increased which is highly related with enhancement of explosive power (Gehri et al., 1998; Luebbers et al., 2003). It is reflected from the results of the present study that structured aquatic plyometric training developed the performance standard of explosive power execution ability. Hence it can be suggested that systematically and scientifically designed aquatic plyometric training programs may be implemented for developing explosive leg power ability to achieve maximum performance. The findings of this study were supported by few previous studies (Atanasković et al., 2015; Coetzee, 2007; Slimani et al., 2016; Söhnlein et al., 2014).

On the basis of the findings of the present study the hypothesis drawn earlier was completely accepted as aquatic plyometric training was found a useful training method for the developments of locomotor skill i.e. speed and explosive leg strength of the athletes. The results of the present study show that systematically designed and scientifically structured aquatic plyometric training develops the speed and explosive leg power ability, two of the most important motor performance factors in almost all games and sports. Therefore, it is suggested that aquatic plyometric training programs may be implemented for developing the aforementioned motor components (speed & explosive leg strength) of the young athletes. After reviewing several literatures, it was observed that the findings of the present study were found to be in agreement with few previous studies which also indicated that aquatic plyometric training gradually has become so popular because it improves the performance factors as well as it reduces additional stress on the musculoskeletal system and helps to prevent them from overuse injuries (Irmischer et al., 2004). Additionally, during the eccentric part of an exercise, the buoyant qualities of water can reduce the load, and during the concentric phase, the drag properties can increase the resistance load(Arazi & Asadi, 2011; Jurado-Lavanant et al., 2017; Kobak et al., 2015; Ravasi & Mansournia, 2008). Hence, the sports trainer became interested in choosing aquatic plyometric training as a more effective and suitable training environment for improving performance with minimum risk of injuries (Senthil Kumar, 2016). Buoyancy always works against gravity to assist the athlete, who feels lighter and experiences less jerks in their joints, which reduces the risk of tendinitis, stress fractures, and other overuse ailments (Coventry et al., 2006; Fabricius, 2011). Again, the drag resistance brought on by the water's viscosity increases the workload placed on the muscles during the concentric phase, perhaps leading to stronger muscles that are faster and more explosive.

Limitations

The current study exclusively examined the effect of Aqua-based plyometric training on young Indian athletes. It is, however, unknown whether the same outcomes will be evident across various training levels. As adaptation responses differ between a pre-adolescent young athletic population and an elite athletic population, it is important to understand how training environment affects the outcome of aqua-plyometric training for an elite athletic population. Therefore, future studies should utilize various athletic populations to examine the effects of aquatic plyometric training programs. It is recommended to the coaches and trainers to implement plyometric training in aquatic medium along with their usual athletic practice sessions while wanting to develop speed, explosive strength and power of the athletes if the facilities to conduct aquatic plyometric training be available.

Strength and Practical Implications of the Study

Aquatic exercise always offers a supportive environment for an athlete that promotes good body thermoregulation, comfort, safety, and a different training environment that enables the coaches to impose greater exercise load with higher intensity and more repetitions during movement execution. Increased turbulence on the water surface happens when an exercise is performed vertically against gravity in an aquatic medium. As a result, the aquatic resistance is maximized due to drag force, which aids coaches in strengthening the active muscles while the athlete feels a reduced weight-bearing condition and thus less vulnerable to injury. When compared to dry-land leaping, aquatic jumping can be a quick and effective way to increase muscular force generation and decrease impact force(Biswas & Ghosh, 2022a, 2022b; M. G. Miller et al., 2001). In addition to sports training, these findings may also be used in preventative exercise and functional rehabilitation programs (Triplett et al., 2009). These results suggest thataquatic plyometric training could be an alternative as well as safe method of training due to less chance of soft tissue injuries than regular plyometric training conducted on dry land. Present study has the same result as the previous studies mentioned above which confirms that though aquatic plyometric training have the same effect on speed and explosive strength but in addition the aquatic plyometric training has a lesser chance of soft tissue injury over the developments of locomotor abilities like speed and explosive leg strength (Fabricius, 2011). Thus, it is recommended to choose aquatic plyometric training in place of other training mediums to develop speed and explosive leg power where the facilities for conducting such training methods are available as it is less vulnerable to musculoskeletal injury too.

CONCLUSION

The subjects of the aquatic plyometric training group (APTG), significantly improved with respect to the control group (CG) due to the intervention of fourteen weeks of aquatic plyometric training. Thus, the plyometric training conducted in aquatic mediums, was found useful for improving motor components of athletic performance along with their regular usual athletic sessions.

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