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Original Article

EFFECT OF VARIED PLYOMETRIC TRAINING IN LAND AND AQUATIC MEDIUM ON ANAEROBIC POWER OF ATHLETES

EFEITO DO TREINAMENTO PLIOMÉTRICO VARIADO EM MEIO TERRESTRE E AQUÁTICO NA POTÊNCIA ANAERÓBIA DE ATLETAS

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RESUMO
O objetivo do presente estudo foi descobrir o efeito do treinamento pliométrico variado (treinamento pliométrico terrestre, treinamento aquapliométrico e treinamento aquapliométrico com colete ponderado) na potência anaeróbica de atletas escolares. Um total de quarenta e oito (n= 48) atletas escolares de nível distrital foram selecionados aleatoriamente. Todos os sujeitos foram divididos em quatro grupos iguais: i) grupo treinamento pliométrico terrestre (n=12), ii) grupo treinamento aquapliométrico (n=12), iii) grupo treinamento aquapliométrico com colete ponderado (n=12) e iv) grupo controle (n=12). O treino pliométrico variado foi intervencionado durante quatorze semanas nos respectivos grupos de treino. No presente estudo, a potência anaeróbia foi considerada como variável dependente e foi mensurada pelo teste de potência de Margaria-Kalamen. Para fazer inferências estatísticas sobre a potência anaeróbica entre os grupos nas condições pré e pós-intervenção, foi utilizada a ANCOVA, seguida do teste post-hoc de Tukey LSD. A significância das médias foi testada no nível 0,05. Diferentes grupos de treinamento pliométrico melhoraram significativamente em relação ao grupo controle na potência anaeróbica. Portanto, vários treinamentos pliométricos foram encontrados como um meio eficaz para o desenvolvimento da potência anaeróbica. Uma diferença significativa também foi observada entre o grupo de treinamento aquapliométrico com colete ponderado e o grupo de treinamento pliométrico terrestre na potência anaeróbica. No entanto, o resto dos grupos experimentais não diferiram significativamente. O treinamento aquapliométrico com colete ponderado é um método de treinamento mais eficaz do que o treinamento pliométrico terrestre para melhorar a potência anaeróbica dos atletas escolares.
Palavras-chave: Atletas; Treinamento pliométrico; Treinamento aquapliométrico; Treinamento aqua-pliométrico com colete ponderado; Potência anaeróbica.

ABSTRACT
The aim of the present study was to find out the effect of varied plyometric training (land plyometric training, aqua plyometric training and weighted vest aqua-plyometric training) on anaerobic power of school athletes. A total of forty eight (n= 48) district level school athletes were randomly selected. All the subjects were divided into four equal groups: i) land plyometric training group (n=12), ii) aqua plyometric training group (n=12), iii) aqua-plyometric training with weighted vest group (n=12) and iv) control group (n=12). The varied plyometric training was intervened for fourteen weeks in the respective training groups. In the present study, anaerobic power was considered as the dependent variable, and it was measured by Margaria-Kalamen power test. To draw statistical inferences on anaerobic power among the groups in pre and post intervention conditions, ANCOVA was used, followed by Tukey's LSD post-hoc test. The significance of the means was tested at the 0.05 level. Different plyometric training groups improved significantly with respect to the control group in anaerobic power. Therefore, various plyometric training was found as an effective means for developing anaerobic power. A significant difference was also observed between the aqua-plyometric training with weighted vest group and land plyometric training group in anaerobic power. However, rest of the experimental groups didn't differ significantly. Aqua-plyometric training with weighted vest is a more effective training method than land plyometric training for improving the anaerobic power of the school athletes.
Keywords: Athletes; Plyometric training; Aqua-plyometric training; Weighted vest aqua-plyometric training; Anaerobic power.

Introduction

Plyometrics are commonly utilized to improve speed and strength, which has an impact on athletes' power, attributes[1]. The ability to apply maximum force as quickly as possible is referred to as muscular power. A maximum muscle contraction against a resistance in the shortest amount of time is referred to as power. Thus, Power = Force × Velocity. The ability to generate power, which is defined as the product of force and velocity, is essential in sports. Power is classified into two categories based on the kind of muscle contraction: aerobic and anaerobic. In anaerobic power production, the muscles contract anaerobically i.e. in less possible time where maximum muscular contraction happens as a result of a large amount of power produced. On the other hand, when muscular contraction happens aerobically it takes time, as a result, moderate power is produced for a certain period of time. Both types of power depend on the rapid production of muscular force. Muscular force generation can be improved by a few training means where plyometrics is one of them. Plyometric is a form of training that has been advocated for sports in which success largely depends on power[2].

Plyometric training basically consist of high-intensity, explosive muscular contractions that execute the stretch reflex; stretching the muscle before it contracts so that it contracts with greater force[3]. Plyometrics training is a type of exercise that involved jumping; bounding and other high impact exercises like standing jumps, spot jumps, bounding, multiple hops and jumps, box drills, and depth jumps etc. that focus on maximizing the stretch reflex of the muscles[4,5]. There are three different phases involved in plyometric training including the eccentric phase, the amortization phase and the concentric phase[6].

In modern-day training plyometric are given in different mediums under various imposed conditions like simple land plyometric training, land plyometric training with wearable load, aqua-plyometric training, aqua-plyometric training with a weighted vest, etc. Depending on the target, the above plyometric training is performed and so chosen to accomplish the objectives. The objective of land plyometric training is to improve the reaction ability of the muscle action spectrum (eccentric deceleration, isometric stabilization, and concentric acceleration) by increasing motor unit recruitment, firing frequency, and synchronization. Plyometric exercises are jumping-like exercises that lead to ground impact forces acting on the body that increases the risk of injury. Ground impact forces are the forces produced by the collision of ground and body, which cause a shock wave to be generated along the body[7]. Due to intense contraction and ground impact forces, plyometric exercises are associated with lower limb injury, muscle damage, and muscular soreness[8.]

Apart from the land surface, plyometrics are also performed in a water medium. Water is a unique exercise medium in which lower-gravity conditions decrease the impact forces on joints, while the water creates resistance to movement[9]. These resistances are buoyancy, viscosity, water drag, and skin friction. An aquatic atmosphere provides an effective means for many aspects of a participant's exercise and conditioning program[10]. In aquatic medium an athlete feels decreased bodyweight due to the vertical component of force acting against gravity, this is also called buoyancy. Buoyancy is defined as the upward thrust acting on any partially or fully immersed object in the opposite direction of gravity[10,11]. Another resistive force viscosity is defined as the internal friction occurring between individual molecules in a liquid, causing resistance to flow[10]. This internal friction or viscous force is associated with the resistance that two adjacent layers of fluid have to move relative to each other, causing resistance to flow[11]. That is why movement in water will experience resistance regardless of buoyancy since water is 800 times viscous than air[10].

The concepts of plyometric training conducted on land are conventional and used mostly by the coaches and trainers from the last two decades for the development of muscle strength and power of the sportsmen. In this training pattern, the advanced training options were also tested by a few experts incorporating additional weight on the athletes in land plyometric training. This hypergravity training on dry land provides few merits but at the same time, this training means involves the high risk of unwanted injury in the muscle-tendon complex, hence not taken into consideration in the present research work. To overcome these difficulties, an aquatic medium is recommended for conducting weight vest plyometric training. Accordingly, the present project was planned to initiate research work related to the effect of varied plyometric training on the anaerobic power of athletes. The researchers were interested to investigate the plyometric training in simple land surfaces, in water medium as well as in water medium with an additional imposed load. Thus the objective of the present study was to find out the effect of varied plyometric training (LPT, APT, APTWV) on the anaerobic power of school athletes.

Methods

Participants

Total forty-eight (N = 48) district level school athletes were randomly selected as participants for the present study from Nadia district of West Bengal situated in the eastern part of India. The age ranged of the subjects was from 12-18 years. The inclusion criteria for participants were; participant needed to have a good fitness and health on routine clinical examination, all the participants should have at least four years' experiences of active participation of district &state athletic meet. Details of demographic information of the participants are given to Table 2.

Procedures

Study design

In this study single pretest-posttest control group design was employed where three experimental training groups and one control group was requited for fourteen weeks. Experimental group-1 underwent land plyometric on grassy turf; experimental group-2 underwent plyometric in a constructed water reservoir with water up to waist level whereas experimental group-3 underwent plyometric in a constructed water reservoir with water up to waist level by adding weighted jacket which was filled in appropriate weight. But the control group did not receive any of the above treatments. Prior to start the training program all groups were given proper warm-up and after the completion of the training they were given cooling down exercises also. The training programs were intervened for three days in a week and 90-120 min total session daily including the time of warm-up and cooling down. Pre & post intervention data were collected on anaerobic power in watts through Margaria-Kalamen anaerobic power test. Before commencing the experimentation; the researcher explained the nature and importance of the study to the subjects. On the basis of their willingness, they have been included to serve as subjects in this study. Written signed informed consent form each subject was taken prior to the commencement of the work where the consent of their guardians was also confirmed. Further necessary permission was taken from the departmental research committee (DRC) of Department of Physical Education, University of Kalyani, where the study was registered after satisfying ethical considerations. In Figure 1 the experimental design is depicted through a flow chart.

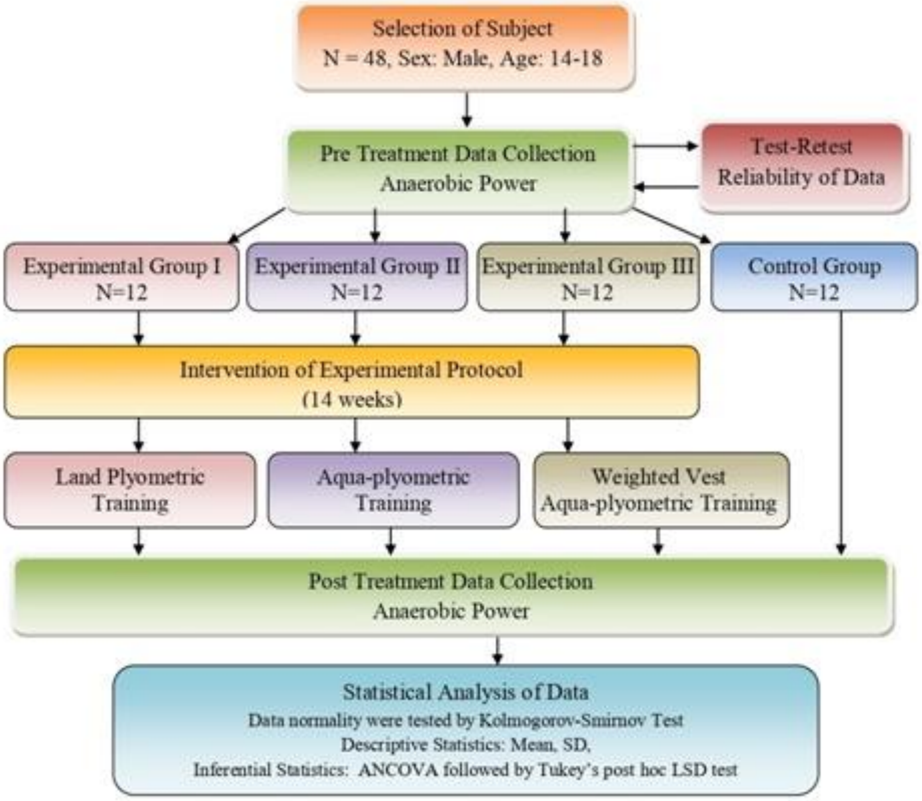

Figure 1 – Experimental Design
Source: authors

Land plyometric training

In land plyometric training seven plyometric exercises those were upward jump & squat, single leg hop (both leg), double leg bounding, split jump, tuck jump, box jump and depth jump were sequentially arranged for the athletes on grassy turf. The intensity and the volume were progressively increased. Two to three minute passive recovery was given between each set of exercise[12–16]. The detail protocol of the land plyometric training is shown in Table 1.

Table 1 – Details protocol of varied plyometric training

Training Week	Training Volume	Plyometric Drill	Set × Repetitions	Training Intensity
I & II Week	96	Side to side ankle hops	2×15	Low
		Standing long jump and reach	2×10	Low
		Double leg hops	3×10	Low
		Upward jump & squat	2×8	Low
III & IV Week	104	Side to side ankle hops	2×15	Low
		Standing long jump and reach	2×10	Medium
		Double leg hops	3×8	Medium
		Upward jump & squat	3×10	low
V & VI Week	118	Single leg hops (alternatively)	2×10	low
		Standing long jump	2×12	Medium
		Double leg hops	3×10	Medium
		Upward jump & squat	3×8	Medium
VII & VIII Week	120	Single leg hops (alternatively)	2×6	Medium
		Standing long jump	2×12	Low
		Double leg bounding	3×8	Medium
		Upward jump & squat	3×8	High
		Tuck jump	4×6	Medium
IX & X Week	106	Single leg hops (alternatively)	2×6	High
		Double leg bounding	3×8	Medium
		Upward jump & squat	3×6	High
		Tuck jump	4×6	Medium
		Split squat jump	2×8	Low
XI & XII Week	98	Single leg hops (alternatively)	2×6	High
		Double leg bounding	3×6	High
		Tuck jump	4×6	Medium
		Split squat jump	2×8	Medium
		Scissor jump	2×8	Low
XIII & XIV Week	86	Double leg bounding	3×6	High
		Upward jump & squat	3×5	High
		Tuck jump	4×5	High
		Split squat jump	3×6	High
		Scissor jump	3×5	Medium

Source: authors

Aqua-plyometric training

In aqua-plyometric training the athletes did same exercise those were upward jump & squat, single leg hop (both leg), double leg bounding, split jump, tuck jump, box jump and depth jump sequentially into plan-fully constructed water reservoir with water up to waist level[14]. The intensity and the volume were progressively increased. Two to three minute passive recovery was given between each set of exercise[12–16]. The detail protocol of the aqua-plyometric training is shown in Table 1.

Weighted vest aqua-plyometric training

In weighted vest aqua-plyometric training the athletes did same exercise those were upward jump& squat, single leg hop (both leg), double leg bounding, split jump, tuck jump, box jump and depth jump sequentially into plan-fully constructed water reservoir with water up to waist level by adding weighted jacket which was filled in appropriate weight. The weighted jacket weighed 5% of their body mass and gradually increases to about 10% of their body mass[17–21]. The intensity and the volume were progressively increased. Two to three minute passive recovery was given between each set of exercise. The detail protocol of the weighted vest aqua-plyometric training is shown in Table 1 for better understanding. In Figure 2 plyometric training in three different mediums has been shown.

A **B** **C**

Figure 2 – The Training conducted in different mediums, A: Land Plyometric Training, B: Aqua plyometric Training, C: Weighted vest aqua-plyometric training
Source: authors

Test Procedures
For all the participants demographic information (age in years, height in cm & weight in Kg.) were measured by standard tools &techniques. Test was administered to collect the data one week before the first intervention session and then one week after the last session. For a particular group all measurements were taken on the same day according to a predetermined schedule. Pre & post intervention data were collected on anaerobic power through Margaria-Kalamen power test. This is a test of power of the lower extremities. Equipment& measuring setup required for conducting the test were stopwatch, tape measure, and flight of 12 steps with a starting line of 6 meters in front of the first step. Each step is approximately 17.5 cm high with the 3rd, 6th and 9th step clearly marked. The vertical distance between the 3rd and 9th step must be accurately measured for use in the results formula. Before starting the test all the athletes were given a few practice runs up the steps to warm up. The athlete stands ready at the starting line 6 meters in front of the first step. On the command "Go", the athlete sprints to and up the flight of steps, taking three steps at a time (stepping on the 3rd, 6th and 9th steps), attempting to go up the steps as fast as possible. The time to get from the 3rd step to the 9th step was recorded by using a stopwatch, starting when the foot was in first in contact with the 3rd step, and stopped when the foot contacts the 9th step. Power (in Watts) is calculated by the formula given below.

$$P = \frac{m \times d \times 9.8}{t}$$

Where P = Power (Watts), m = Body mass (kg), d = Vertical distance, between steps 3 & 9 (meters), t = Time (seconds). g = 9.8 is the gravitational constant.

Statistical analysis

Test-retest reliability of data was tested by computing co-efficient of correlation. Data normality was tested by Kolmogorov–Smirnov test. To find out the significant difference in anaerobic power among the groups in the pre and post intervention condition; analysis of covariance (ANCOVA) was used. To find out the exact location of the difference between different groups, Tukey's LSD post-hoc test was employed for further analysis. The significance of means was tested at 0.05 level. The Kolmogorov-Smirnov test of normality was performed by *social science statistics* software and rests of the statistical calculations were performed by *vassar stats* a statistical computation software package.

Results

All the three plyometric training groups were improved significantly with respect to the control group in anaerobic power. A significant difference was observed between the weighted vest aqua-plyometric training group and land plyometric training group in anaerobic power. On the other hand there was no significant difference between land plyometric and aquatic plyometric training group in anaerobic power. It was also found no significant difference between aquatic plyometric training and aqua-plyometric training with weighted vest training group in anaerobic power. The details of the results are shown in Table 2-4 for better understanding the research outcomes.

Table 2 – Personal characteristic of the participants in baseline

Name of the Group	No. of Subjects	Age (years) Mean ± S.D	Height (cm.) Mean ± S.D	Weight (Kg.) Mean ± S.D
LPTG	12	15.25 ± 1.86	154.92 ± 7.44	46.09 ± 6.36
APTG	12	15.67 ± 1.56	155.92 ± 5.50	48.54 ± 5.40
APTGWV	12	15.42 ± 1.83	158.33 ± 8.17	49.58 ± 4.62
CG	12	14.75 ± 1.54	154.33 ± 4.91	45.40 ± 7.39
Total No. of Subject	48			

Note: LPTG = Land plyometric training group; APTG= Aqua-plyometric training group; APTGWV= Aqua-plyometric training group with weighted vest; CG=Control group

Source: authors

Table 3 – Analysis of Co-Variance (ANCOVA) of anaerobic power (Watts) among LPTG, APTG, APTGWV and CG in baseline, post treatment and adjusted post test

Test	LPTG	APTG	APTGWV	CG	Source of variance	SS	df	MS	'F' Ratio	*p* -value
Baseline Mean ± SD	922.86 ± 161.69	1067.64 ± 207.64	1084.66 ± 253.61	933.14 ± 151.17	Between	265753.65	3	88584.55	2.265	0.094
					Within	1720710	44	39107.04		
Post Treatment Mean ± SD	1008.77 ± 193.00	1195.94 ± 229.69	1245.46 ± 293.85	917.92 ± 146.19	Between	859041.85	3	286347.28	5.793*	0.002
					Within	2174975.68	44	49431.27		
Adjusted post test Mean	1096.15	1123.62	1154.36	993.96	Between	160699.09	3	53566.36	28.373*	0.00001
					Within	81181.04	43	1887.93		

Note: LPTG = Land plyometric training group; APTG= Aqua-plyometric training group; APTGWV= Aqua-plyometric training group with weighted vest; CG=Control group; SD=Standard deviation; SS=Sum of square; df=Degree of freedom; MS=Mean squares.*The table values required for significance at .05 level with df (3,44) and (3,43) were 2.820 and 2.825 respectively

Source: authors

The calculated ANCOVA tests for anaerobic power among the four groups were significant (0.05). It indicated that there was significant difference among four different groups of subjects in post-treatment and adjusted post-test condition (Table 3).Differences of anaerobic power due to plyometric training in three experimental conditions for baseline, post treatment & adjusted post treatment in the experimental groups (LPTG, APTG, and APTGWV) and Control Group have been shown in Figure 3.

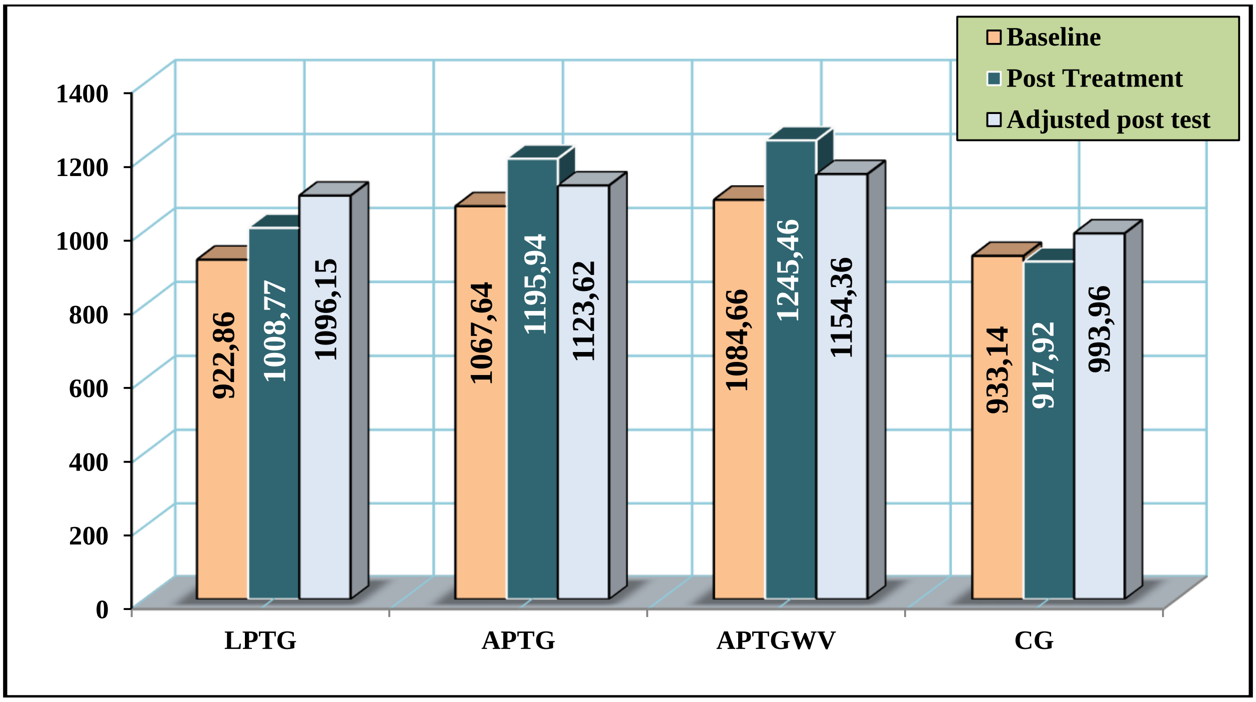

Figure 3 – Differences of anaerobic power (watts) in baseline, post treatment & adjusted post treatment for the experimental groups (LPTG, APTG, APTGWV) and control group

Source: authors

Table 4 – Tukey's LSD post-hoc test on anaerobic power in adjusted post test mean score for different groups

Adjusted Post Test Mean Scores				**Mean Difference**	**Required confidence interval**
LPTG	APTG	APTGWV	CG		
1096.15	1123.62			27.469	35.770
1096.15		1154.36		58.216*	35.770
1096.15			993.96	102.186*	35.770
	1123.62	1154.36		30.747	35.770
	1123.62		993.96	129.655*	35.770
		1154.36	993.96	160.402*	35.770

Note: LSD= Least significant difference; LPTG = Land plyometric training group; APTG= Aqua-plyometric training group; APTGWV= Aqua-plyometric training group with weighted vest; CG=Control group. *Calculated value of critical difference at 0 .05 level of significance with df (43) was 35.770

Source: authors

In Table 4 the conformity of the exact difference among the mean value of different group in anaerobic power were tested by Tukey's LSD post hoc test which indicated that all the three experimental groups significantly differed with the control group whereas significant difference among the experimental groups was only observed between LPTG & APTGWV. Other experimental groups did not differ significantly with each other.

Discussion

The present study was designed to compare the effectiveness of land plyometric training, aqua plyometric training, and weighted vest aqua-plyometric training on anaerobic power of school athletes. At the end of the 14 weeks experimentation, it was found that all the three training groups led the increases of the anaerobic power in comparison to control group. The findings of the several previous studies on plyometric training in various medium may be mentioned here as supportive literature of the above result which suggested that improved lower body strength and power production ability plays a key role in success for developing performance in sports[22–27]. During a plyometric movement, the muscles undergo a very rapid switch from the eccentric phase to the concentric phase. This stretch-shortening cycle (SSC) decreases the time of the amortization phase that in turn allows for greater than normal power production[20–27]. This enhancement of increased power production ability may lead to the improvement of power ability of the three training groups in comparison to the control group.

Again the result of the present study on anaerobic power also indicated that there was no significant difference between LPTG & APTG and APTG & APTGWV after the intervention of fourteen weeks varied plyometric training programs. It proved that the training programs had an identical effect for developing anaerobic power. Various studies as searched by the researchers which compared the effect of LPT vs. APT and some other studies compared APT vs. APTWV on anaerobic power performance. Some of those studies reported that LPT was as effective as APT for anaerobic power development[25]. Similarly, few studies also reported that APT & APTWV had an identical effect for the development of anaerobic power. As per the finding of the present and previous research studies aquatic medium is suggested as an alternative means of land plyometric which have greater risk of musculoskeletal injury with or without weight vest. Where as in aqua plyometric training there are comparatively less chance of injury even in weighted vest condition.

The findings of the present study also indicated that in anaerobic power the APTGWV had improved significantly than LPTG. This result also proved that APTWV was more effective than LPT for the development of anaerobic power. It can be explained by the fact that buoyancy always acts against gravity that provides support to the athlete to feel reduced body weight that gives less jerks on the joints and lowers the risk of tendonitis, stress fractures and other overuse injuries[28,29]. Again the drag resistance due to the viscosity of water increases the work load of muscles during the concentric phase resulting in the possibility of better power improvement of the muscles[12,28–30].

Incorporation of additional weight during LPT exercises that lead to receive high ground impact forces on the body having increased risk of muscle soreness and injury. Ground impact forces are the forces produced due to the collision of ground and body. This impact force generates a shock- wave which flows along the body[31]. This impact force may cause severe damage of muscles and joints and may lead to overuse injuries[32]. During plyometric exercise, specifically in the eccentric contraction phase, may cause *Delayed Onset of Muscle Soreness* (DOMS), which is generally experienced by the athlete between 24–72 hr after normal to hard exercise[33].Thus the researcher incorporated additional weight in aquatic medium for minimizing the chance of injury and interested to investigate the effect of weight vest aqua plyometric training (APTWV) on anaerobic power[29,31]. Thus while selecting training medium (land or weight vest aquatic) for developing anaerobic power through plyometric training. It is reflected from the results of the present study that structured plyometric training whether performed on land surface or aquatic medium even with additional weight incorporated on the subjects in aquatic medium, develops anaerobic power ability consequently the performance standard increases. Hence it can be suggested from the findings of the study that systematically and scientifically designed varied plyometric training programmes in aquatic medium with weight vest develops anaerobic power ability to a great extent.

Conclusion

Fourteen weeks varied plyometric training significantly improved the anaerobic power of the school athletes in comparison to control group and also confirmed that the weighted vest aqua-plyometric training improved better than the land plyometric training. No significant difference was also found in aqua-plyometric vs. land plyometric and aqua-plyometric vs. weighted vest aqua-plyometric training for improving anaerobic power ability. Thus it is recommended to all concerned while selecting training medium for developing anaerobic power through plyometric training, aquatic medium will be better than land surface and aqua plyometric training with weight vest will be the best choice.

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