Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 12 [10] September 2023 :352-365

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
REVIEW ARTICLE **OPEN ACCESS**

Impact of Intensity and Volume of Plyometric Training on Physical Performance Parameters in Athletes: A Systematic Review and Meta-Analysis

Shweta Panchal[1], Pooja Bhati[2*], Pooja Anand[3], Sajjan Pal[4]
Faculty of Physiotherapy, Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana, India
Email: pooja.bhati092@gmail.com.

ABSTRACT
Existing literature states that plyometric training (PT) has beneficial effects on the physical performance parameters of athletes which is the key element for better performance. The present study aims to systematically review the impact of intensity and volume of PT on various physical performance parameters of athletes. Systematic search was performed on the databases Pub Med, Web of Science and Proquest using group of MESH and "NON-MESH "terms (("Athlete") OR (Player") AND (Plyometric exercise) OR (Stretch- shortening exercise) OR ("Jump training") OR ("Plyometric training ") AND ("Performance"). This systematic review included only randomised control trials (RCTs) investigating the effect of at least 4 weeks of PT on physical parameters in adolescent and adult athletes. Fourteen full text studies were qualitatively assessed by the PEDro scale and 4 out of 14 met the criteria for quantitative analysis. Majority of the studies were of fair quality (n=7), 6 were of good quality, and 1 was of poor quality. Majority of reported data showed significant improvement in physical performance parameters such as squat jump (SJ), vertical jump (VJ), depth jump (DJ), horizontal jump (HJ), counter moment jump (CMJ), lateral jump (LJ), change of direction ability (CODA), sprinting. Quantitative analyses revealed significant improvement in CMJ [Standardized Mean difference (Confidence intervals), SMD (CI), 0.73, 0.12 to 1.35, p=0.02] and CODA (SMD (CI), -0.79 (1.56 to -0.03), p=0.04) with progressively increasing intensity and volume. Findings suggests that PT is more effective at higher intensity and low volume than any other dosage. Combination, if performed for a period of 4-6 weeks.
Keywords: athlete, plyometric exercise, intensity, volume, performance

Received 23.07.2023 Revised 21.08.2023 Accepted 21.09.2023

INTRODUCTION

Plyometric training (PT) is one of the most popular and widely used training strategies to improve physical performance in team sports players [1]. It is a strength training method based on stretch-shortening cycle [2] which can be defined as the ability of the neural and musculotendinous systems to produce maximal force in the shortest amount of time and develops during the transition from a rapid eccentric muscle contraction to a rapid concentric muscle contraction [3]. PT includes muscle lengthening followed by the muscle shortening therefore, it may improve flexibility, increases the amount of stored elastic energy in the muscles [4], joint proprioception and stimulate more muscle units result in higher neural firing frequency [5,6]. These physiological changes ultimately enables the muscles to produce greater magnitude of work in the same time [7] which helps an athlete to become more economical in actions such as sprinting(acceleration, deceleration), jumping[squat jump(SJ), drop jump (DJ), vertical jump (VJ), horizontal jump (HJ), counter movement jump (CMJ)] and quick changes of direction. These physical parameters are determining factors for sports performance outcome in field sports [3]. The exercises characteristics triggering performance enhancement are intensity, duration and recovery duration [2] program length, volume and exercise mode. Previous studies demonstrated high intensity exercise can be used safely and effectively [2] with implying reduced volume of training for inducing comparable training adaptations than other plyometric modes [2]. Already existing literature stated there will be some effect of PT intensity and volume. Now it need to be understand the optimum dosage which will be producing significant improvement in physical performance parameters of athletes. It is already accepted by the principal of specific adaptation of imposed demand that specific the training exercises to a competitive movement greater will be the transfer of training [8] .At elite level it becomes a challenge to continue isolated training for improving specific physical development and explosive actions, when emphasis is mostly placed on technical development due to congested match fixture and associated travels. [2]. This knowledge might help coaches and physical fitness trainers to optimize specific training strategy [1] and concern regarding the safety of PT for athletes will also be minimal, if a proper technique is combined with appropriate progression [9]. Considering all the points' aim of this paper is to systematically reviewing the literature on the impact of PT intensity and volume on physical performance parameters of athletes.

MATERIAL AND METHODS

The systematic review titled "Impact Of Intensity And Volume Of Plyometric Training On Physical Performance Parameters In Athletes" conducted under preferred reporting items for systematic review (PRISMA) statement.

Data sources and search strategy:

Advanced search for systematic review from the date of inception up till March 2021 was done on databases PubMed, Web of Science, Proquest. Group of MESH and "NON-MESH "terms (("Athlete") OR (Player") AND (Plyometric exercise) OR (Stretch- shortening exercise) OR ("Jump training") OR ("Plyometric training ") AND ("Performance") were used by combining them with appropriate BOOLEAN operators AND and OR to make the search more precise. Besides the database search, references of the relevant articles were also screened.

Inclusion and exclusion criteria:

The inclusion criteria consisted of: (1) Clinical trials administrating plyometric training for at least 4-weeks; (2) Only randomized control trials on athletic population; (3) Randomized control trials assessing physical parameters such as sprint time, lower limb power, agility; (4) Adolescent and adults both age groups were recruited; (5) Studies which have mentioned plyometric intensity and volume.

The criteria for exclusion of studies in the review were: (1) Studies comprising other forms of exercise training such as strength, combined training, resistance training, Aerobic training; (2) Review articles, case reports, and thesis, dissertation and conference papers; (3) Epidemiological studies (cross-sectional and cohort studies)

Data collection and analyses:

Selection of studies:

All the retrieved articles after applying advanced search on each database were transferred to the EndNote Reference Manager (EndNote™ online, Clarivate analytics) to remove the duplicates and to combine the result.

The authors (S.P. and P.B.) applied inclusion criteria to titles and thereafter selected articles were screened by their abstract. After screening the abstract, the full text of each relevant articles was obtained and the same author independently reapplied the inclusion and exclusion criteria blinded to the author and publication data. Final set of articles which matched the inclusion criteria were screened by the author (S.P.) to include them into the review. A third reviewer (P.A.) was there to resolve disagreements at each point.

Data extraction:

Two reviewers (S.P. and P.B.) independently, after designing the data extraction forms, data regarding the characteristics of the trial (year conducted, study design, duration) the participants (sample size, age, gender), intervention (type, intensity, number of sessions, duration, progression) control treatment, main outcome measures (lower limb power, agility, sprint time) and extracted the main findings. Authors of the respective study were contacted via e-mail if report data was unclear and incomplete. A third reviewer (P.A.) was there for consultation if any conflict raised between the two reviewers.

Quality assessment:

PEDro scale which consists of 11-point, in which 10 criteria were rates as either "YES" (score-1) or 'NO" (score=0) for each included study, as the first criteria did not receive any score, was used for examining the methodological qualities of studies. Studies which score <4 classified as poor , if score is 4-5 average, and if score is 6-8 good, or excellent if score is more than 8, maximum score can be 10 quality, studies were rated by adding all the criterion scores for methodological quality [10].

Data synthesis and analyses:

Meta-analysis was performed for only those studies which scored good on qualitative assessment and providing sufficient information on either of the pre-established outcome measures. The standardized mean difference (SMD) [SMD = MD/SD pooled], where MD is difference in means of the intervention and control groups and SD is the standard deviation, was used to define the effect estimates for physical parameters. Two physical parameters were edible for meta-analysis CODA (lesser the time(S) taken shows greater the improvement) and CMJ (greater the jump height (CM) greater the improvement) at different intensities and volume of plyometric training. The meta-analysis was performed using Cochrane collaboration's review manager 5.3 software. Cohen's d criteria were used to determine magnitude of effect size (small <0.2, moderate 0.2-0.5, large >0.5). Statistical significance was set at 5% (0.05). Cochrane's Q tests of heterogeneity was determined. Heterogeneity between the studies was quantified using the I^2 test, which measures the percentage of the observed variability between effects estimates beyond chance. A value of I^2 <25% indicates low heterogeneity, 25-75% indicates moderate heterogeneity and >75% indicates high heterogeneity.

RESULTS

Study selection:

Through database searching 1470 records were initially identified, from these duplicates were removed (n=334) before study titles were screened and removed for relevance (n=1136). After this, article abstracts were screened for relevance (n=100). We then inspected full text articles (n=44) and after applying all inclusion/exclusion criteria,30 studies were excluded due to lack of solely plyometric training group, non-randomized control trail, non-athletic population and study of less than 4 weeks and were left with 14 randomized controlled trials eligible for qualitative analyses,[11,12,13,3,14,15,1,16,17,9,18,2,19,20].

Study characteristics:

Study design:

Total of 14 studies identified, 7 were randomized parallel group trails [11,12,13,14 ,9,2,19], 3 were randomized parallel group multiple arm comparative control trails [15,1,18], 1 was randomized two group repeated measures experimental design [3], 1 was randomized parallel group multi arm between group repeated measures experimental design [16], 1 was randomized parallel group active control trial [17], 1 was randomized parallel group comparative control trial [12]. Details regarding the study design and the control group are shown in table-1.

Participants:

14 of included studies comprised a total number of 535 participants with sample sizes ranging from 18 to 76 and the average age of the participants ranging from 10 to 25 years. 3 trials included only female athletes in their studies, 3 trials included only male athletes, and 8 trials included both male and female athletes. Majority of trials assessed adult age group ranging 18-25 years, 2 trials assessed middle age adolescents ranging 15-17 years, 3 trials assessed young adolescent age group ranging 11-14 years. These studies comprised 18 plyometric training groups and 235 total number of participants involved in plyometric training intervention, 2 studies out of 14 didn't mentioned about the number of participants in experimental group [15, 20].

Intervention:

At least one of the groups in each study used plyometric training as an intervention with stated volume and intensity of protocol. Time duration of the plyometric training in a day ranging from 15-20 minutes to 50 minutes. Number of training sessions per week is twice except one study which have given the training for 5 days in a week. Duration of training protocol applied ranging from 6 weeks-16 weeks. 4 of total studies stated both exercise intensity and volume , in which [11], has progressively increased intensity and volume both with the progression of duration of training protocol, in which [2,19] had used same volume but high intensity of plyometric training. 4 studies mentioned about given volume of plyometric training in which [13,1,16] was comparing low vs. high volume of plyometric training, [19] has used same volume throughout the study duration. 6 of total have mentioned only intensity of training protocol in which [14,15,17,9] have progressively increased training intensity with the time duration, [3] have used the high intensity plyometric training [12] have used the progressively increasing intensity of training protocol.

Outcome measures:

Most of the studies have examined the jumping and sprinting abilities of the athletes. [11 ,13,3,14,15,1,17,9,19,2] have measured the sprinting ability of athletes by using sprinting ability test of 10,20,30,35,40 metres'. [12,3,15,1,17,9,19,2] have measured the counter movement jumping, [3,15,9]have measured the squat jump, [12,1,2]have measured the vertical jump, [11,12,13,1,19,12,20]have measured the agility, [3,15,9,2] have measured the multiple bound jump, [17,2]have measured the reactive strength index.

Quality of trials:

The average PEDro score for all studies was 5.21/10 (good quality). The scoring of each study for each criteria of the quality assessment scale is defined in table-2. Based on quality scoring, 6 studies were of good quality [12,13,3,14,15,1], 7 were of fair quality [11,16,17, 9,18,2,19], 1 was of poor quality [20]. Good quality studies shared potential methodological strength as all provided information on performed randomization, conceal allocation of the participants, baseline similarity, measures of key outcomes, statistical analyses and point measures of variability. Despite having good score on quality scale maximum of them have not discussed the blinding of subjects, assessor and therapist. Seven studies were of fair quality, had common procedural weakness of none concealed allocation, baseline similarities, blinding of subject, assessor and therapist. One was of poor quality had not mentioned the randomization procedure, allocation of participants, blinding of subject, assessor, therapist, didn't having intention to analyse. [1,2]two studies didn't mentioned the point measures of variability, which is one of the statistical quality of study. Only two out of all [14,1] have mentioned the blinding of subjects and therapist which was adding methodological strength to the study.

Effect of PT on physical performance parameters of athletes:

Seven studies [11,12,13,3,1,18,2] reported statistically significant improvement in physical parameters like lower limb explosive power actions SJ, VJ, DJ, HJ, CMJ, LJ, sprinting, CODA and 7 studies showed positive adaptation but not statistically significant improvement in the assessed parameters of athletes. Overall results were inconclusive on effective dosage required to increase performance.

Magnitude of effect: results of meta-analysis:

The meta-analysis involved two studies and analysis showed statistically significant improvement in CMJ performance of athletes (fig- 1), the pooled analysis revealed large effect size (SMD=0.73, 95% CI= 0.12 to 1.35, p = 0.02) and the significant improvement in CODA with smaller effect size (SMD= -0.79, 95%CI= -1.56 to -0.03, p = 0.04). (fig – 2) with progressively increasing intensity and volume with the progression of time of plyometric training, while studies which applied the same volume and high intensity of PT throughout the training session, their pooled analysis revealed statistically insignificant improvement in CODA of athletes with large effect size (SMD= 0.07, 95%CI= -0.31 to 0.45, p = 0.72) (fig- 3)

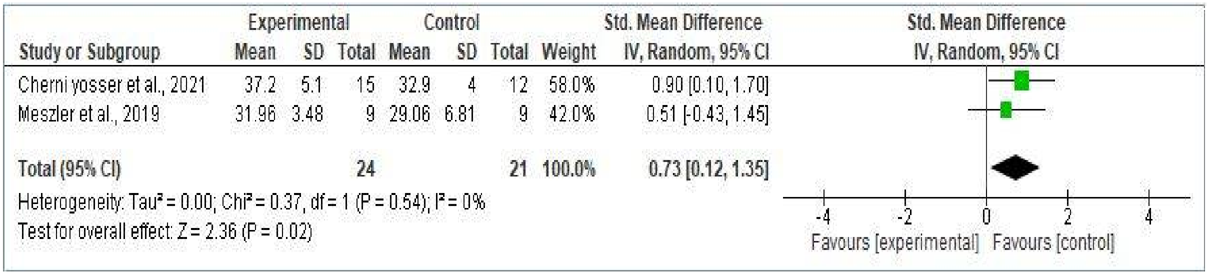

Figure- (1) Forest plot comparing the plyometric training progressively increasing intensity and volume vs control on counter movement jump in athletes.

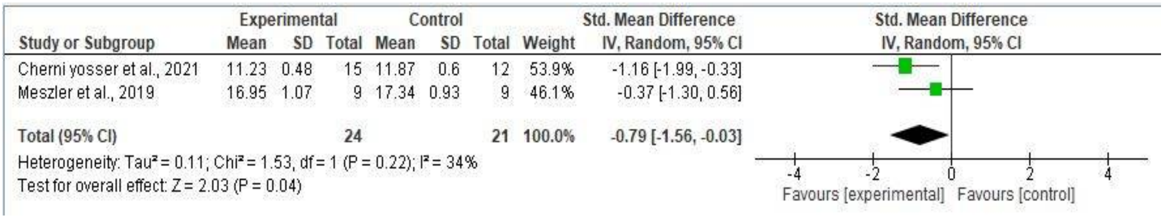

Figure- (3) Forest plot comparing the plyometric training progressively increasing intensity and volume vs control on change of direction ability in athletes.

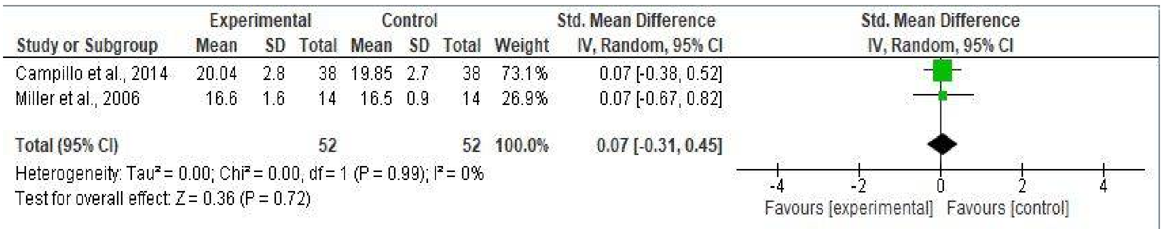

Figure- (3) Forest plot comparing the plyometric training with same volume and high intensity vs control on change of direction ability in athletes.

Study	Study design	Population	Intervention	Variables	Main outcomes
[11]	Experimental design	27 female(F) basketball players (aged 21.0 ±2.6 yrs). PT group(grp.) (n=15),control(cont.) grp (n=12)	PT (ploymetric training) for – 2 sessions/wk/8 wks, combined exercise- low to medium intensity(Int.) hurdle jump & high int. drop jump(DJ) & int. and vol. inc. progressively ,JH inc. from 0.4-0.5mtr, no. of ground contacts inc. every 2 wk, starting with 72 contacts and reaching to 126, rest interval of 48hrs in between(btw)	sprinting , jumping, agility, peak power, verage power and associated neuromuscular adaptations	PT program insignificantly modify body (Bd.) composition (body fat %,), inc. leg muscle vol., thigh ,muscle volume(vol), max. cross-sectional area) No significant changes in cont. group (grp.) Change of direction ability (CODA) & sprint didn't reach to statistical significance in experimental (exp) grp. Squat jump (SJ) & counter movement jump(CMJ) were significant in tested muscles of exp. grp except vastus medialis. Comparing exp. to cont. results were insignificant in jump height (ht)- SJ,CMJ.
[12]	Randomized experimental study	18 F, Exp. Grp (n=9;age= 15.8±1.2 yrs , body ht= 176.4±8.6cm, bd,wgt=63.5±8.6kg) Cont. grp (n=9; age=15.7±1.3, bd wgt= 66.1±8.9kg, bd.ht=177.5±7.4cm)	7-wk program , 3 wks were preparatory phase, followed additional 3 wks with inc. vol. and 1 wk with dec. vol. no of jumps inc. with 61-70 to 84-100/ session over 6wks.subjects were instructed to max. jumping ht, distance and minimize ground contact time during drills	Illinois agility test, t- sprint test, CMJ-R;L, balance , MVC-60 flex-ext. , 180*flex-ext., H:Q	IAT (p=0.000), MVC 180ext (p=0.035), MVC 180flex (p=0.056), CMJ (p=0.058), post-hoc analysis raveled CMJ reduced significantly in PT grp (p=0.012), No significant change was observed for TST, balance, MVC60ext &flex, Hemstring : Quadriceps(H: Q) ratio.
[13]	Randomized parallel grp design	T-21, low-vol. plyometric grp (PG)(n=10), high-vol. PG(n=11), (mean±SD; age-17±0.8yrs, wgt-70.1±6.4, ht- 177.4±6.2)	LPG 1day protocol- 4x5 DJ from 60cm ht. followed by 2 subsequent jump over two obstacles 15cm ht, 4x6 horizontal jumps as well as 4x6 jumps over 15cm ht. HPG= performed same protocol 2d/ wk. Both grps performed- COD & Sprint training (3x3short shuttle runs+4COD each for an amount of 36 COD) for 8wks	Long jump(LJ), triple hop test-R;L, 10m sprint, 30m sprint, 40m sprint and 505 agility	LJ (p= 0.304), triple hop test rt.(p=0.225), triple hop test lt.(p=0.541), 10m sprint (p=0.425), 30m sprint(p=0.439), 40m sprint(p=0.078) & 505 agility(p=0.412)
[14]	Randomized experimental design	31 total, cont. grp= 14, intervention grp= 17, age- 12±0.8	Each grp participated in 3 training sessions, Warm-	CMJ, SJ, LJ, multiple 5-bounds9 (55MB), speed	-At CMJ & 5MB changes for both were p>0.05, PTG improved in SJ & L J

			up was common, training session= soccer technical skills, tactics, speed and sprint workload and small-sided games. PT= 15-20mins/2 wk/ 72 hrs apart, during wk 1= 5 repts,inc. by 1 every wk, at the end of 6th week repts/set were 10 at max int..	10m-30m , T-test, yo-yo intermittent endurance test-1(YYIET-1)	-CG showed improvement in LJ & decrement in SJ -both grps demonstrated marked reduction of sprint times in 10m, Sprint 30m increased for both T-test (PTG;P=0.002, CG;P= 0.002) YYIET1 (PTG: P=0.689) and inc. by 7.9% for CG (P=0.68)
[15]	Parallel grp randomized control trial	37M athletes (n=16),for women (n=14), age, ht., bd mass for male=11, female= 6 were 23±2.4yrs, 1.76±0.76m, 73±8.5kg)	2 grps, low-to-high grp (L-H) , high-to-low grp(H-L),Two week familiarization phase ,H-L GRP= emphasis on drop ht. ,L-H grp= conventional DJ with emphasis on vertical jump(VJ) ht, both grps completed 5setsx4repts/2 WX 6W with 48-72-h rest period btw training sessions with inc. int.	10, 20 m sprint time , 505 time	10m sprint (ES OF H-L=-0.44, L-H= 0.05) 20m Sprint time (ES OF H-L= -0.07, L-H=0.34) 505 time (ES H-L=0.006, L-H= -0.003)
[16]	Experimental design	T- 68, (age: 14.6±0.6 yrs; ht:176.5±6.4 cm; body mass: 66.5±12.2 kg),	16-wk training, warm-up=jogging, dynamic stretching ex, calisthenics, and preparatory ex, 5 mins cool-down, CG didn't participate in any training program. Strength training (ST) ex with an int. btw 40 &70% of 1RM with 1 to 2 sets of 8 to 12 repts, int. inc over 16-wk training period from 40 to 70°/° of 1 RM. Each session preceded by a 10-min warm up and lasted ~35 min, PT performed with 2 to 3 sets of 6 to 8 repts/2wk with int. progression	Thigh muscle volume, SJ CMJ, MBJ test, medicine ball throw (MT), Sprint (5 and 10-m) and Sit and reach (SR)	Significant effects of time on SJ (*p*<0.001), CMJ (*p*<0.001) and MBJ (*p*<0.001) significant group by time interaction on SJ (*p* <0.001), CMJ (*p*<0.001) and MBJ (*p*<0.05) Post-hoc analysis revealed combined training significant. PT significantly inc. SJ (*p*<0.05), CMJ (*p*<0.001) MBJ (*p*<0.01). CG showed no changes, CTG showed significant dec in SJ by 2.11cm (*p*<0.001), in CMJ by 2.35 cm(*p*<0.001) & MBJ by 2.86 cm(*p*<0.001) PTG showed significant regression in SJ by 1.64 cm(*p*<0.001), in CMJ by 1.48(*p*<0.001) and MBJ by 1.64 cm(*p*<0.001).

			low-moderate-high.		
[17]	Experimental design	44 M, (age= 22.5±5.0yrs,bd mass= 69.3 ±9.8kg, ht= 1.7±0.1m, BMI= 22.4±2.7kgm-2, 3-grps (PT 1D,n=15), (PT 2D n=12),(CG,n=12)	2 grps, 1d PT grp (PT1D/Wx6W), 2 d PG (PT2D/ Wx6W) & cont. grp, sets x repts was same for both grps. Ex were arm swing horizontal- CMJ, single leg lateral jump, arm swing, vertical-CMJ, single leg lateral jump, drop jump, dominant leg drop jump, non-dominant leg drop jump	Straight sprint, CODA, VJ,HJ, repeated sprint ability, CMJ	Linear straight sprint 5m-15m, (Effect size (ES)=small to large), CG (ES=moderate(mod.), not significant for all grps. CODA = PT2D(ES=large), PT1D (ES= mod.), No change in CG Repeated sprint ability (RSA)PT1D & CG improved significantly, PT2D(ES= mod.), only 30m RSA was (p<0.01),VJ;PT2D (mod. to large), CG(ES=large to very large) significantly worsened in all types of VJ CMJ of CG & VJ of PT1D no statistical difference, HJ, PT2D significantly improved in posttest, PT1D and CG were not significant. No VJ & HJ was significant (grp x time)
[18]	Experimental design	36 M, (age 20.3±1.6yrs, bd mass 91.63±10.36kg, stature 1.82±0.05m	3 grps low vol. PG (LPG;n=10), high vol. PG (HPG;n=9), (CG;n=10) 2 sessions/wk/6 wks high and low PT programme included testing DJ from 30cm,45cm and 60cm along with two footed hopping	Reactive strength index (RSI), leg stiffness	Reactive strength index, LPG (30cm;ES= 0.58) (45cm;ES=0.58)(60cm;ES=0.54) HPG (30cm;ES= 0.38) (45cm;ES=0.52)(60cm;ES=0.24) CG (30cm;ES=-0.15) (45cm;ES=-0.26) (60cm;ES=0.14) Leg stiffness ,LPG (ES=0.06),HPG (ES=0.54),CG(ES=0.08)
[19]	Experimental design	41 F (21.8 ± 2.1 yrs of age; 1.76 ± 0.06 cm; 60.8 ± 7.0 kg), PG (n = 21), or skill-based-conditioning-program (n = 20)	PT - 2/w/12-w, warm-up=10-15 min, cool-down= 25-40 min &10-15 stretching. Lower limb (L.L) PT -leg hops, VJ, tuck jumps, lat/diagonal jumps, broad jumps, obstacle jumps, diff types of box jumps & DJs. U.L PT = push-ups, jumping spider (combinations), clapping push-ups & diff ex with med. ball in diff directions with the progressive int. low-mod-high.	Sprint-20m, standing broad jump (SBJ), CMJ, medicine ball throw (MBT)	Significant effects for grps for S20M (p = 0.01), SBJ (p = 0.01), CMJ (p = 0.01) & MBT (p = 0.01). Significant effects on time for body mass (p = 0.04), S20M (p = 0.01), SBJ (p = 0.01), CMJ (p = 0.01) & MBT (p = 0.01). Significant “Group x Time” interactions were found for S20M (p = 0.02), SBJ (p = 0.01), CMJ (p = 0.01) & MBT (p = 0.01)
[20]	Experimental design	T-27, TG(n=14,age=11.7±1.0yrs, B.M=43.0±16.6kg,ht=1.58±0.2, bd fat=12.4±4.6%),CG(n=13,age=2.1±1.oyrs, B.M=38.1±4.1kg, ht=1.54±0.03m, bd fat=13.3±4.3)	50min./2W/10 W PT of various intensities, continuous or intermittent	Peak power output, sprint running velocity(35,40 m), squat jump,	-EG inc. all VJ (SJ &CMJ) and horizontal jump (HJ) performances relative to controls.

			running at various fractions of max. velocity, sprinting over distances of 10, 15 and 20m and flexibility exercises. All subjects also merged weekly in school physical education sessions of 40mins. And consisted mainly of ball games.	CMJ,DJ and lower limb muscle vol., 5-MB,	-Force velocity test parameters showed no intergrp differences after 10 wks of PT -Neither grp showed any significant changes in total left and thigh muscle volumes. - Thigh CSA statistically increased in the exp. grp after PT -Sprint velocity over short distances improves (p<_0.01). Vmax showed smaller gains (p<_0.05).
[21]	Experiment al design	57 M, resistance training(RTG) grp(n=12),PTG (n=12),complex training grp(CTG)(n=12),cont. grp(n=21) of similar age grp (20.3±1.6yrs)	2 sessions/W/9W ks, 10mins warm up - light jogging or cycling, RTG - high-load wgt training, PTG - PT training without wgt bearing ex., CTG - high load wgt training followed by plyometric ex., set by set. CG - regular soccer training. Training session lasted 15-20 mins. Training vol. total no if sets x repts were not altered during training for all grps, but for RT & CT load for wgt bearing ex was inc. by 5% from 1-RM each 3wks.	SJ, planter flexion(flex.), knee flex, knee extension, concentric peak torque, eccentric peak torque,5m, 20m sprint, CMJ, agility performance	All training grps inc. 1-RM squat, knee ext and planter flex strength compared with CG. RT inc concentric peak torque of knee extensor & flex muscles in dominant limb compared to CG, non-dominant limb was non-significant. No significant changes in non-dominant limb. The RT& CT elevated in eccentric peak torque of the knee flex muscles of dominant limb, CT inc eccentric peak torque comparing with CG and PT. H:Q ratio was non-significant all grps. 20m sprint significant for all grps. 5-m sprint, agility test, SJ, CMJ=non-significant btw grp.
[22]	Experiment al design	Total 76 players, TG(n=38; 13.2±1.8yrs) CG(n=38; 13.2±1.8yrs)	2/W x 7W PT session - 21 mins included 2 stesx10repts of DJ from 20,40 and 60m int. remains high but vol. didn't change	CMJ, RSI 20,40, 20m sprint, IGT, 5MB test, VJ test, maximal kicking distance test, 5-alt leg bounds.	No significant difference b/t grps baseline measurements, TG = RSI20 (P<0.01), RSI40 (p<0.01), MKD (p<0.01), & agility (p<-0.05), Significant or small inc. in CMJ, RSI20, RSI40 and MB5, CG non-significant. Sprint test (TG= not significant), (CG= <0.001) IGT(TG=p<0.001), (CG=p<0.001),MKD (TG P<0.001, significant, CG= non-significant
[23]	Experiment al design	24M, PL(n=12,age=21.9±1.7yrs,bd mass=75.9±2.7kg,bd ht=180.1±4.0cm) CG(n=12,age=22.7±1.4, bd mass= 78.6±3.1kg, ht= 180.6±3.7cm)	PT- 2/w/6w warm-up= 10 mins jogging, stretching, performing 8 to 10 running drills in diff. directions & 4 to 6 sub max running strides. W1& W2 were	MVC (maximal voluntary contraction), T-agility test, Illinois agility test (IAT), DVJ,	ANOVA revealed significant group by time interaction effects for TAT (***p*** < 0.01), IAT (***p*** < 0.05), DVJ (***p*** < 0.01) & MVC (***p*** < 0.01). PT grp post-hoc tests revealed the greatest improvement in DVJ (9%) (***p*** < 0.05), and MVC

			preparatory phase, followed by 3 more wks (W3–W5) with inc vol, & (W6) with dec vol to taper.PT routines- double-leg jumps, HI- single-leg ex in sagittal & lat directions.		increased (7%) from pre- to post-training (***p*** < 0.05). Small but significant improvement in TAT and IAT (2.5% and 1.7%, respectively) (***p*** < 0.05). In controls there was no change over time in any of the measured variables.
[24]	Experimental design	28 subjects, at least 18 years,	6-wk PT included 2 training sessions/w Training vol ranged from 90 foot contacts to 140-foot contacts per session, int. of the ex. inc for 5 wks before tapering off during 6 wk ,	agility	PG improved T-Test agility times by −0.62 ± 0.24 sec, cont. grp times were virtually unchanged. IGT change score, a significant group effect was found, PTG improved their force plate agility test times by −26.37 ± 21.89 msec & the cont. changed their times by −0.98 ± 6.33 msec.
Ht- height, Bd- body, T- total, F- female, M- male, EX.- exercise, Wk- week, Wks- weeks, wt- weight, yrs- years, BM- body mass, movt- movement, Cont.- control, grp.- group, exp.- experimental, PTG- plyometric training group, PT- plyometric training, LPG- low volume plyometric group, ST- strength training, CG- complex training, RT- resistance training, HPG- high volume plyometric group, repts- repetitions, max- maximal, vol.- volume, int.- intensity, mod. vol.= moderate volume, H-L- high to low, L-H- low to high, L.L- lower limb, U.L- upper limb, Lat.- lateral, ext- extensors, flex- flexors, MVC- maximum voluntary contraction, btw- between, SD- standard deviation, ES- effect size, inc- increase, dec- decrease, rt- right, lt- left, COP- centre of pressure, H:Q- Hemstring : Quadriceps, VJ- vertical jump, VJH- vertical jump height, DJ- drop jump, DJH- drop jump height, SJ- squat jump, LJ- lateral jump, CMJ- countermovement jump, GRF- Ground reaction force, RSI- reactive strength index, DVJ- drop vertical jump, IAT- Illionis agility test, TAT- T-agility test, 5-MB- Multiple bound jump, YYIET-1- Yo-yo intermittent endurance test,					

Table-3.3 (Quality scoring of the studies based on PEDro scale)

Trials	Eligibility criterion specified	Random allocation	Concealed allocation	Baseline similarity	Blinding of subjects	Blinding of therapist	Blinding of assessors	Measures of key outcomes from more than 85% of subjects	Intention to analyses	Between group statistical comparison	Point measures of variability	Total score	Quality
[11]	Yes	No	No	No	No	No	No	Yes	Yes	Yes	Yes	4/10	Fair
[12]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10	Good
[13]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10	Good
[14]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10	Good
[15]	Yes	Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	6/10	Good
[16]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10	Good
[17]	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	No	6/10	Good
[18]	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5/10	Fair
[19]	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5/10	Fair
[19]	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5/10	Fair
[20]	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5/10	Fair
[21]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	No	5/10	Fair
[22]	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5/10	Fair
[23]	Yes	No	No	No	No	No	No	Yes	No	Yes	Yes	3/10	Poor

DISCUSSION

Purpose and main findings:

This systematic review was conducted to summarize and evaluate the existing literature on the effect of intensity and volume of plyometric training on the physical performance parameters of athletes. As per the findings of qualitative analyses plyometric training (PT) showed positive effects on physical performance parameters of athletes at different intensity and volumes. Meta-analysis suggested PT can significantly improve CODA and CMJ in athletes with the progressively increasing intensity and volume.

Impact of intensity of PT on physical performance parameters of athletes:

Out of all, total 6 studies mentioned about the effect of intensity of PT protocol on physical performance. [19] examined progressively increasing intensity of PT comprising both unilateral and bilateral maximum intensity exercise for 6 weeks, 2/week in young adolescent athletes which produced significant improvement in parameter such as depth vertical jump (DVJ), agility and isometric knee extensor strength, lower limb strength. In contrast, study of [17] trained the athletes at same dosage of intensity of PT for 12-weeks for twice a week resulted in improving sprinting capacity by 8%, jumping and throwing capacity and significant physiological decrease in body mass (03%).

Another study trained young adolescent athletes for 10 weeks showed significant gains in sprint velocities (Vs., V5m, V maximum), vertical jump height, power (SJ, CMJ and DJ), horizontal jump length, multiple bound jump (MB5), mean thigh cross-sectional area only in male runners. However, total leg and thigh muscle volumes, absolute and relative muscle power, maximum pedalling velocity and maximum force remained unchanged after PT, which could be attributed to the phenomena of SSC which might not have positively influenced the maximum pedalling velocity. At the same time control treatment also increased their absolute peak power by 10.0% suggesting that gains were because of the standard training rather than PT [9]. On comparing the findings of this study [9] with [19] 6 weeks progressively increasing intensity of PT showed significant improvement in all the physical parameters except CODA in which changes were relatively small and the protocol was highly significant in improving DVJ of young adolescent athletes that was because of inclusion of unilateral and bilateral maximum intensity exercises in training protocol. This led author to speculate that high impact jumping and hopping exercise seem to have significant short-term effect on DVJ (9%).

Furthermore, [15] trained middle adolescent athletes at moderate intensity for 12 weeks, which was effective in improving 5m and 10m sprint and muscle power of the athletes. Performance like SJ, CMJ and muscle flexibility remain unchanged, though he trained athletes for 16 weeks but results could not be significant, which can be explained by the type of exercise utilized in the training program. Another important point that is to be noted from the study of [15] is that detraining negatively affected the athletic performance and suggested that a continuous inclusion of PT should be considered in the training regime of athletes.

In contrast, training young adults at high intensity for twice a week for 6 weeks showed improvements in physical parameters like 10m sprint, agility, squat jump, lateral jump. Performance in 5 multiple bound jump and the physiological adaptations like intermittent endurance testing showed no statistical changes [9]. In accordance with the findings of this study [9,17] trained the same age group for 12 weeks with progressively increasing the intensity and [15] 16 week moderate intensity protocol was selectively improving the physical parameters like sprinting, muscle power and less significant in improving CMJ, SJ and muscle flexibility. These findings suggests that a shorter duration PT at similar intensities is equally effective to a longer duration PT. Therefore, a time effective approach should be considered by the coaches for training athletes.

[14] compared two intensities of PT in his study, high to low intensity and low to high intensity, improvement in 10m sprint was observed in high to low intervention group. No other significant improvements in performance were observed for either group. Low to high intensity group found an improving trend on measures of lower limb muscle power and linear sprint performance but not significant. Despite the observed improvements in 10m sprint performance in the high to low group, non-significant and unclear results were observed in CODA performance for both the group.

In summary, the majority of plyometric intensity based studies on athletic population demonstrated significant positive changes in sprint performance [14, 9] jumping performance horizontal and vertical both, positive but not significant changes were seen in CODA irrespective of age and duration of protocol. CODA results were still unclear stated by [3,14] perhaps a protocol with higher frequency and volume of COD drills could be more effective. Previous literature which indicates that eccentrically accentuated training can enhance the ability of athletes to produce and control force eccentrically, allowing for greater decelerations from faster approach velocities during CODA tasks involving large braking component

[21,22,23]. Additionally, the greater braking impulses produced by athletes with superior eccentric strength capacities may also allow for more rapid reacceleration during a COD task as a result of the storage and utilization of elastic energy [23, 24].

Studies have demonstrated that eccentric overload and eccentrically accentuated training can enhance muscle strength, power and stretch shortening cycle function resulting in improved sprint and COD performance [25, 21, 25–27]. In a systematic review of the chronic adaptations to eccentric training by [28] highlighted the growing body of evidence in support of eccentric training as a means of inducing a novel adaptive signal for neuromuscular adaptations that can improve athletic qualities such as those mentioned above including strength, power and SSC performance. [5,6].

Studies of [15,9] showed increment in the muscle cross sectional area, both the studies incorporated adolescent population young and middle respectively. This shows the adaptive potential of muscle morphology in adolescent athletes. It has been found that muscle volume and CSA similarly increase during maturation with the highest rate of muscle growth [30] which corresponds to the age of players in the current study. Children of same age group experience a natural increase in neural co-ordination and central nervous system maturation during childhood [31] which combination with the fast muscle actions demonstrated during plyometric training may provide an augmented training response [32]. Therefore it is likely that growth and development changes could override the training stimuli and consequently diminish the possible influence of plyometric exercises on changes in anthropometric indices [7].

Impact of volume of PT on physical performance parameters of athletes:

Four out of all studies mentioned the volume of plyometric training protocol. PT of 8 weeks with two different volumes showed meaningful differences between low volume training groups (LPG-trained for once a week), high volume training group (HPG-trained for twice a week) on middle adolescent athletes. Except for the CODA, both the groups offered same meaningful improvements in jump, speed, agility capabilities, leg stiffness and horizontal jump performance (HJ). However, no statistical differences were seen between two different volume PT groups. HPG had beneficial effects on COD test, while LPG didn't report meaningful change [13]. On comparing, the findings of this study [13]with [16] trained young adult athletes for 6-weeks results indicated that high as well as low volume PT program produces similar performance enhancements in terms of repeated sprint index (RSI).

In contrast, training young adult athletes for 6-weeks with same training volume once a week and twice a week were capable of improving RSA, sprint, VJ performance. PT 1D was effective in improving 5-m sprint, 15m sprint CODA, HJ and RSA. Whereas, PT 2D was effective in improving 15m sprint. Interestingly both PT group displayed clinically important improvement in CODA, with PT 2D showing better results than PT 1D. These results suggest that exposure to only, weekly plyometric training session may cause important performance changes in athletes [1].

[18] Trained young adult athletes for twice a week for 9 weeks with same volume and found that PT was effective in improving muscle strength and 20-m sprint performance. Players were only performing one set of each plyometric exercise drills so the author of same study stated this is a very low volume plyometric training compared to previous studies.

In summary, majority of the studies on athletes demonstrated significant positive changes in sprint performance (5, 15, 20, 30 40mtrs), jump performance, vertical and horizontal jump ability, RSA, RSI and lower limb muscular strength which is usually associated with improvements in relative strength in power-related abilities [33]. the positive increment in lower extremity strength is related with improvements in neuromuscular function that likely to occur in response to PT [34] and RSI is a measure of SSC capability and more importantly being efficient at overcoming eccentric forces, it can be proposed that the subjects in both the HPG & LPG groups will have increase their SSC capabilities, author also identified that the increase in leg stiffness was mainly due to the decrease in vertical displacement of the center of mass. They propose that as the hopping frequency increases, the stiffness of the spring mass system increases and the displacement of COM decreases, results in decrease in contact time and the ability is created to bounce off the ground in less time.

Many studies in this review [1,13,16] compared the two volume of PT with training frequency of 1-2 days/week. [13]has shown the improvement in all above-mentioned physical parameters. However since no difference between their results were observed therefore, author recommended using low PT volume equivalent to 80-100 jumps a week [1]. Similarly studies in this review [1,16] has suggested that the similar or better training effect can be accomplished with a low volume training program as compare to high volume training program.

With regards to gender, studies on both the genders and separately showed significant improvements in all the measured physical parameters, but three of all included only man and one included both the genders, so results could be speculated as male specific. On commenting age group most of the studies included young adults only one study included the middle adolescent athletes, but the results were equally significant for both the age groups.

Impact of intensity and volume of PT on physical performance parameters of athletes:

PT twice a week for 8 weeks the study of [11] with increasing volume and intensity in young adult athletes was not sufficient to induce significant improvement in physical performance, results showed enhancement in sprinting speed, squat, 10, 20 &30 meter sprint performance and CMJ, peak torque and average leg power performance with time interaction didn't reach significance. However, there were significant gain in CODA, RMS values for vastus medialis muscle, maximal cross section area. On comparing, the findings the study of [11] with 7 weeks of PT program of [12] on middle adolescent players where authors hypothesized that the program would produce improvements in jump performance strength, H: Q ratio, agility and balance. Data provide evidence that the training program used, didn't improve the measured variables except for knee extensor strength despite inclusion of unilateral and bilateral movements equally like depth jumps, hurdle-jumps and lateral cone jumps in training program. Study showed that 7-week PT was not effective in agility development [12].

In contrast, the study of [2] trained twice a week for 7 weeks with same volume and high intensity induced significant and small to moderate improvements in CMJ, RSI 20,40, MB5, CODA, MKD & 2,4 time trial performance. Another study for 6 weeks twice a week on young adults with same volume and progressively increasing intensity PT improved times in agility test measure [20]. Which shows the efficacy of high intensity and same volume of PT.

In summary, 8 -7 weeks of training with increasing volume and intensity didn't led to significant change in physical performance parameters such as sprint, SJ, CMJ, peak torque, average leg power with the time interaction, agility, balance, which could be attributed to both structural and neural factors such as the angle adopted during plyometric exercise which was insufficient to induce an improvement in muscle stiffness and thus greater storage and release of elastic energy [35] and insufficient number of jumps performed during training program. These disparate results may reflect differences in the type and intensity of programs and the heights of jumps undertaken. While one [11] study showed significantly positive effects on CODA, RMS, VMM, knee extensor strength. Both have trained only female athletes of middle adolescents and young adult age group [11,12]. For this previous literature suggests the necessity to extend the intensity of jumps and to plan programs with higher heights.

Training young adults for 6-7 weeks of plyometric protocol with same volume and high intensity showed significant improvements in agility, CMJ, RSI 20, 40, MBJ5, MKD, 2.4 KM time trial [2,20]. In accordance of their results [2] has stated that replacement of technical exercise with low-volume, high-intensity drop jumps exercise was effective at improving several explosive actions and endurance capacity in youth players. After critically reviewing the literature on the intensity and volume of PT, it can be stated that future studies should include the training program with multiple- directional, unilateral and bilateral exercise given the nature of sprinting and other explosive movements on field [2] to get more clear results on particular dosage of intensity and volume of PT program.

Strength and limitations

The present review has some limitations. First, because of the heterogeneity in reporting data only 14 studies were included in meta-analysis, among those only 4 showed homogeneity for only two variables CODA and CMJ and lastly only two studies were included in quantitative analysis, which is very limited data to generalize the results. Considering these limitations, the findings of meta-analysis should be interpreted with caution. Despite these limitations, the present review has some potential strengths. This review appraising 14 RCTs providing discernment on the effect of intensities and volume of plyometric training only on athletic population. Second, findings of this review might help researchers, coaches and physical trainers to formulate optimum PT regimens within provided fixture of time during matches. This review outlines, limitations in the existing literature and propose extensive opportunities for future researchers on PT its effects on physical parameters of athletes.

Recommendations for future research

A well-designed high quality RCTs with appropriate exercise should be conducted on athletic population. More future studies are required on different dosage of PT with respect to intensity and volume to make the strong conclusion on the prescription of PT for athletes. There is strong need to study the exercises incorporation of which would produce equivalent benefit to CODA as like other explosive actions of lower limb of athletes after PT. Comparison of different volume of PT would be extremely relevant due to extreme of scant literature. As per the review findings, 4–6-week protocol significantly benefited the physical performance parameters of athletes, more number of studies comparing the 4-6 week protocol duration on different age groups need to be done to concrete the results. The present review was unable to formulate optimal dose of PT that led to optimum improvement of physical parameters of athletes but discussed the suggestion for the training of physical parameter like CODA and dosage (volume & intensity) of PT which could be beneficial for appropriate improvement in the less time for particular age group.

CONCLUSION

The present review demonstrated that plyometric training has positive adaptations on physical performance parameters of athletes of adult as well as adolescent age group of both the genders at different intensities and volume. Although deriving a definite conclusion would be difficult, due to heterogeneity in the available data, this rigorous systematic analysis of existing evidence allows one to conclude that PT is an effective form of training for athletes for improving their explosive lower limb power (SJ, VJ, DJ, HJ, LJ, CMJ), sprinting, COD ability, but conclusive comments on optimum dosage of intensities and volume with the respective training duration would be difficult at this stage. As per findings of this review, PT at high intensity and low volume is significantly improved the physical performance parameters of athletes. PT duration of 4-6 weeks produced meaningful physiological adaptations in order to improve physical performance parameters of athletes. However, in the future, there is a strong need for highly specific studies on the effects of either PT intensity, volume or both PT intensity and volume to precisely elucidate optimum dosage of PT and its impact on physical performance parameters in athletic population.

ACKNOWLEDGEMENT

The author would like to sincerely thank SGT University and all the authors of the studies included in the review fir their help and providing information regarding their studies.

COMPLIANCE WITH ETHICAL STANDARDS

Conflicts of interest: The authors declare no conflicts of interest.

REFERENCES

1. Y. Javier, P. Vasco, E. Herriko, and D. Castillo, (2017). "Effects of Two Different Volume-Equated Weekly Distributed Short-Term Plyometric Training Programs on Futsal Playe....," J. strength Cond. Res., vol. 31, no. 7, pp. 1787–1794,
2. R. Ramirez-campillo and F. Gallardo-fuentes,(2018). "Effect of Vertical, Horizontal, and Combined Plyometric Training on Explosive, Balance, and Endurance Performance of Young Soccer Players," J. strength Cond. Res., vol. 29: 90-98.
3. A. Tabouris, T. Metaxas, , (2018). "Note . This article will be published in a forthcoming issue of the International Journal of Sports Physiology and Performance . The article appears here in its accepted , peer-reviewed form , as it was provided by the submitting author . It has not been," Int. J. Sports Physiol. Perform., no. 10, 2018.
4. K. Kubo, (2007). "Effects of Plyometric and Weight Training on Muscle–Tendon Complex and Jump Performance," Med. Sci. Sport. Exerc., no. 10, pp. 1801–1810
5. E. jean mclaughlin,(2001). "A Comparison Between Two Training Programs and Their Effects on Fatigue Rates in Women," J. Strength Cond. Res., vol. 15, no. 1, p. 25.
6. C. Pienaar and B. Coetzee, (2012). "Changes in Selected Physical, Motor Performance and Anthropometric Components of University-Level Rugby Players After One Microcycle of a Combined Rugby Conditioning and Plyometric" J. strength Cond. Res., vol. 27, no. April, pp. 398–415
7. M. Sigmund et al., (2017). "Training-induced changes in physical performance can be achieved without body mass reduction after eight week of strength and injury prevention oriented programme in volleyball female players," Biol. Sport, vol. 34, no. 2, pp. 205–213.
8. N. S. Wales,(2009). "Effect of an acute bout of p lyometriC," J. strength Cond. Res., vol. 23, no. 4, pp. 1181–1186.
9. M. S. Chelly, S. Hermassi, and R. Shephard, (2015). "Effects of In-Season Short-term Plyometric Training Program on Sprint and Jump Performance of Young Male Track Athletes," J. strength Cond. Res., vol. 29, no. 8, pp. 2128–2136.
10. K. Hariohm, V. Prakash, and J. Saravankumar, (2015). "Quantity and quality of randomized controlled trials published by Indian physiotherapists," Perspect. Clin. Res., vol. 6, no. 2, pp. 91–98.
11. Y. Cherni et al., (2020). "Neuromuscular Adaptations and Enhancement of Physical Performance in Female Basketball Players After 8 Weeks of Plyometric Training," Front. Physiol., vol. 11, p. 588787.
12. B. Meszler and M. Váczi,(2019). "Effects of short-term in-season plyometric training in adolescent female basketball players," Physiol. intenational, vol. 106, no. 2, pp. 168–179.
13. M. Bianchi, G. Coratella, (2018). "Comparative effects of single vs. double weekly plyometric training sessions on jump, sprint and COD abilities of elite youth football players.," J. Sport. Med. hysical Fit., p. 8804.
14. J. Singh and B. B. Appleby,(2018). "Effect of Plyometric Training on Speed and Change of Direction Ability in Elite Field Hockey Players," sports, no. 6, pp. 1–14.
15. R. Hammami, J. Moran, R. Borji, and S. Sahli,(2018). National Strength and Conditioning Association, no.
16. D. S. Croix, "Jeffreys , Mark , De Ste Croix, Lloyd , Rhodri S , Oliver , Jon L and Hughes , Jonathan, (2019). "The effect

of varying plyometric volume on stretch-shortening cycle capability in collegiat," J. Strength Cond. Res., vol. 33.34-39
17. B. Gjinovci, K. Idrizovic, O. Uljevic, and D. Sekulic, (2017). "Plyometric Training Improves Sprinting , Jumping and Throwing Capacities of High Level Female Volleyball Players Better Than Skill-Based Conditioning," J. Sport. Sci. Med., vol. 16, no. October, pp. 527–535.
18. P. Krustrup, (2014). "Short-Term Performance Effects of Three Different Low-Volume Strength-Training Programmes in College Male Soccer Players," J. Hum. Kinet. Vol., vol. 40, no. March, pp. 121–128.
19. S. Sciences and N. Sciences,(2013). "Short-Term High Intensity Plyometric Training Program Improves Strength , Power and Agility in Male Soccer Players," J. Hum. Kinet. Vol., vol. 36, no. March, pp. 17–26.
20. M. G. Miller, J. J. Herniman, M. D. Ricard, C. Christopher, and T. J. Michael, (2006)."The effects of a 6-week plyometric training program on agilitY," J. Sport. Sci. Med., vol. 5, pp. 459–465.
21. M. S. Chelly, S. Hermassi, and R. Shephard,(2015). "Effects of In-Season Short-term Plyometric Training Program on Sprint and Jump Performance of Young Male Track Athletes," J. Sport. strengh Cond. Res., vol. 29, no. 8, pp. 2128–2136.
22. O. Gonzalo-skok et al., (2017). "Eccentric-Overload Training in Team-Sport Functional Performance : Constant Bilateral Vertical Versus Variable Unilateral Multidirectional Movements," Int. J. Sports Physiol. Perform., vol. 12, no. 7, pp. 951–958.
23. T. Santos, (2016). "Mechanical d eterminants of f aster c hange of," J. strength Cond. Res., vol. 31, no. 3, pp. 696–705.
24. M. De Hoyo et al., (2016). "Effects of 10-week eccentric overload training on kinetic parameters during change of direction in football players," J. Sports Sci., vol. 0414,102-108.
25. P. Taylor, T. Spiteri, J. L. Cochrane, N. H. Hart, G. G. Haff, and S. Nimphius, (2013). Effect of strength on plant foot kinetics and kinematics during a change of direction task," Eur. J. Sport Sci., vol. 13, no. 6, pp. 646–652
26. S. Athletes, (2017)."Effects of a Six-Week Strength Training Programme Sport Athletes," sports, vol. 83, no. 5, pp. 18–20.
27. S. Maroto-izquierdo, D. García-lópez, and J. A. De Paz,(2017). "Functional and Muscle-Size Effects of Flywheel Resistance Training with Eccentric-Overload in Professional Handball Players by," J. Hum. Kinet. Vol., vol. 60, pp. 133–143
28. J. Douglas, S. Pearson, A. Ross, M. Mcguigan, and J. Douglas, (2017). "Chronic Adaptations to Eccentric Training : A Systematic Review," Sport. Med., vol. 47, no. 5, pp. 917–941
29. J. Tous-fajardo, O. Gonzalo-skok, J. L. Arjol-serrano, and P. Tesch, (2016). "Enhancing Change-of-Direction Speed in Soccer Players by Functional Inertial Eccentric Overload and Vibration Training," Int. J. Sports Physiol. Perform., vol. 11, pp. 66–73.
30. H. I. K. Anehisa and Y. A. K. Awakami, (2014). J. strength Cond. Res., vol. 28, no. 8, pp. 2236–2243, 2014.
31. I. Loturco, (2015). "A Comparative effects of single vs . double weekly plyometric training sessions on jump , sprint and COD abilities of elite youth football players," J. Sports Med. Phys. Fitness.90-95
32. H. Kanehisa, S. Ikegawa, N. Tsunoda, and T. Fukunaga, (2007). "Strength and Cross-Sectional Areas of Reciprocal Muscle Groups in the Upper Arm and Thigh During Adolescence," Int. J. Sports Med., vol. 16, no. 01, pp. 54–60
33. L. A. Pereira et al., (2015). "Transference Effect of Vertical and Horizontal Plyometrics on Sprint Performance of High-level U-20 Soccer Players Transference effect of vertical and horizontal plyometrics on sprint performance of high-level U-20 soccer players," J. Sports Sci.,3 ;80-89
34. G. Markovic and P. Mikulic, (2010). "Neuro-Musculoskeletal and Performance Adaptations to Lower-Extremity Plyometric Training," Sport. Med., vol. 40, no. 10, pp. 859–895.
35. S. D and M. D, (1981). "Specificity in strength training: a review for the coach and athlete.," Can. J. Appl. Sport Sci., vol. 6, no. 2, pp. 87–92

CITATION OF THIS ARTICLE

Waghmode M S and Patil N N. Bioremediation of Acetaminophen and Hydroxychloroquine by biosurfactant producing strain *Bacillus velezensis.* Bull. Env.Pharmacol. Life Sci., Vol 12 [10] September 2023: 352-365