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Original Article

Effect of electromyostimulation and plyometrics training on sports-specific parameters in badminton players

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ABSTRACT

Badminton is one of the world's most popular racquet sports, demanding motor skills such as agility and vertical jump mainly for striking a shuttlecock. This study compared the effects of four weeks of plyometric training and electromyostimulation of knee extensor and ankle plantar flexor muscles on agility, 30-m sprint, lower limb explosive power and jumping ability amongst badminton players. State-level badminton players ($n = 90$) were randomly allocated into three groups: plyometric (PG), electromyostimulation (EG) and control group (CG), each with 30 players. Randomized-to-Groups Pretest-Posttest Design with two experimental (plyometric and electromyostimulation) groups and a control group was used. The plyometric training was carried out two times/week while the EMS training was four times/week for four weeks. The control group did not receive any intervention. All three groups continued their general badminton training throughout the study. Players were assessed for agility, a 30-m sprint, a standing broad jump and a vertical jump height before and after four weeks. A significant improvement ($p = 0.01$) in 30-m sprint time was observed (3.83%) in PG as compared to controls. Jumping ability was significantly improved in both the PG and EG in comparison to the controls (4.45%, $p = 0.003$ for PG and 3.95%, $p = 0.048$ for EG). No significant improvement was found in agility and lower limb explosive power in either of the PG or EG groups in comparison to the controls. Plyometric training showed significant improvement in sprint time and jumping ability, whereas electromyostimulation training showed significant improvement only in jumping ability.

Introduction

Badminton is considered a safe individual non-contact sport due to the lack of physical contact between players. To hit the shuttlecock from a variety of postural positions, a player must quickly change direction, jump, lunge at the net, and rapidly swing their arms.[1] A player's physical attributes, such as muscular strength and endurance, power, quickness, agility, and flexibility, as well as overall stability and coordination, are critical.[2] Athletic performance, as well as day-to-day activities and work responsibilities, rely heavily on a person's ability to generate a great level of power and muscle strength. A variety of training methods can be used to build muscle strength.[3]

Eccentric motions are followed by concentric contractions in the same muscle region in plyometric exercises. Therefore, plyometric training is used in sports requiring high power output as it creates more tension in muscles compared to other slow-speed resistance training and is used in many sports training. Acceleration, strength, and limb power may all be improved by muscle strength training.[4] Plyometric training increases the strength of muscles using both musculotendinous elastic components, as well as stretch reflexes.[5] Plyometric training has shown improvement in vertical jump height, sprint timing in soccer players[6] and vertical jump height when added with weight training. Plyometric exercises are implemented in various forms depending on the purpose of the training program. Despite the advantages of plyometric training, the principal issue of determining the optimal elements of a plyometric program remains inconclusive.

Electromyostimulation (EMS), also known as neuromuscular electrical stimulation (NMES), is a technique for stimulating muscles without causing pain. The use of EMS to augment or replace voluntary muscular

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Abbreviation:

PG	Plyometric Group	m	meter
EG	Electromyostimulation Group	cm	centimeter
CG	Control Group	mA	milliampere
M	Male	min	minute
F	Female	s	second
EMS	Electromyostimulation	30-m sprint	30-meter sprint
NMES	Neuromuscular Electrical Stimulation	1RM	One-repetition maximum
BMI	Body Mass Index	ATP	Adenosine triphosphate
SBJ	Standing Broad Jump	T-effect	time effect
VJH	Vertical Jump Height	I-effect	intervention effect
CMJ	Countercurrent Movement Jump	TxI interaction	time × intervention interaction
ACSM	American College of Sports Medicine	ANOVA	One-way analysis of Variance
kg/m^2	Kilogram/(meter)^2	ANCOVA	Analysis of covariance
		SD	Standard deviation
		p	Level of significance

activation has been around for a long time in rehabilitation settings, such as muscle re-education and contraction facilitation. More particularly, electromyostimulation (EMS) has been previously employed as a means of strength training in healthy humans.[7]

Indeed, initial significant improvements in vertical jump height have been observed,[8] although the validity of these findings is still debatable.[9] For example, Malatesta et al. only noticed improvements in vertical jump ten days after the EMS training ended. Improvements in performance caused by EMS could be due to neurological mechanisms[9,10] or changes in the muscle itself,[11] but they appear to be linked to training durations. Short EMS training periods (four weeks) resulted in neural changes, which are evidenced by increases in both muscle activation and electromyographic activity,[8,11] and (three weeks) EMS strength program in preseason tennis training has shown improvement in all training parameters like maximal quadriceps strength, vertical jump height and shuttle sprint time.[12] On the other hand, longer training periods (e.g., eight weeks) result in considerable muscular hypertrophy[11] and (twelve weeks) EMS application has shown improvement in muscle strength and power in elite rugby players on particular tests.[7]

The dissimilarities in the results may be due to differences in EMS parameters such as the number of repetitions, frequency of stimulation, twitch and rest periods; pre-training condition of the subjects and specificity of the tests to detect changes after EMS training.[13] Enhancing the effect of combined EMS and Plyometric training on sports parameters is well established. Both of these methods have shown improvement in sports performance parameters in sports like volleyball, basketball, soccer, rugby, and tennis but the effects of these techniques have not yet been conducted on badminton players. Therefore, this study investigates the effects of four-week plyometric training and electromyostimulation in combination with specific training on the physical performance of badminton players at the state level. The null hypothesis of the study was that there will be no significant difference in either of plyometric training or electromyostimulation on agility, 30-m sprint, standing broad jump (SBJ) and vertical jump height (VJH) after four weeks in badminton players.

Materials and methods

Study design

Randomized-to-Groups Pretest-Posttest Design with two experimental groups, namely, the plyometric group (PG) and electromyostimulation group (EG), and a control group (CG). The method of double-blinded randomization was used for the allocation of players into three groups.

Participants

A total of 120 State-level badminton players at different sports academies in the National Capital Region were screened however only 90 were included as per the inclusion criteria (Fig. 1). Players were included if they met the criteria of age between 17 and 24 years, male, BMI between 18 and 24.9 kg/m^2, the experience of sports specific training at least for two years, participated in different competitions at least for three years, and able to stand on one leg for > 30 s, and if able to fit in to the plyometric training prescreening. Any players who had any history of cardiovascular, metabolic, or neurological disease and any lower extremity injury or surgery twelve months prior to baseline assessment and involved in any other plyometric training program were excluded.

Ethical approval

Before the procedure, a written consent form was taken from all the players, and they were informed regarding the training protocol given to improve sports performance. The study was conducted as per the WMA Declaration of Helsinki (1964) and its later amendments. Enrollment and allocation were done by a researcher who was neither part of the intervention nor part of the assessment.

Sample size

The calculation of the sample size was carried out using the G*Power v.3.1.9.7 program, with an α error of 0.05, a power ($1 - \beta$ error) of 0.80, the effect size of 0.289, and the number of groups as three, obtaining that a total of 120 participants is required, with 30 individuals in each group.

Interventions

Prescreening of each subject was assessed at baseline and after completing four weeks. The data was collected from the badminton academies of the National capital region of India. All players in the plyometric training received plyometric training for four weeks.

Plyometric training

The training program was built based on the reviews of previous studies, including plyometric training and based on the recommendations of intensity and volume from ACSM's Foundations of Strength Training and Conditioning.[14] The plyometric training is described in Table 1. Training volume ranged from 90 to 120 foot contacts per session while the intensity of the exercises increased during four weeks.[7]

The plyometric training program was conducted twice a week for four weeks with a minimum of two days of rest between training sessions. The

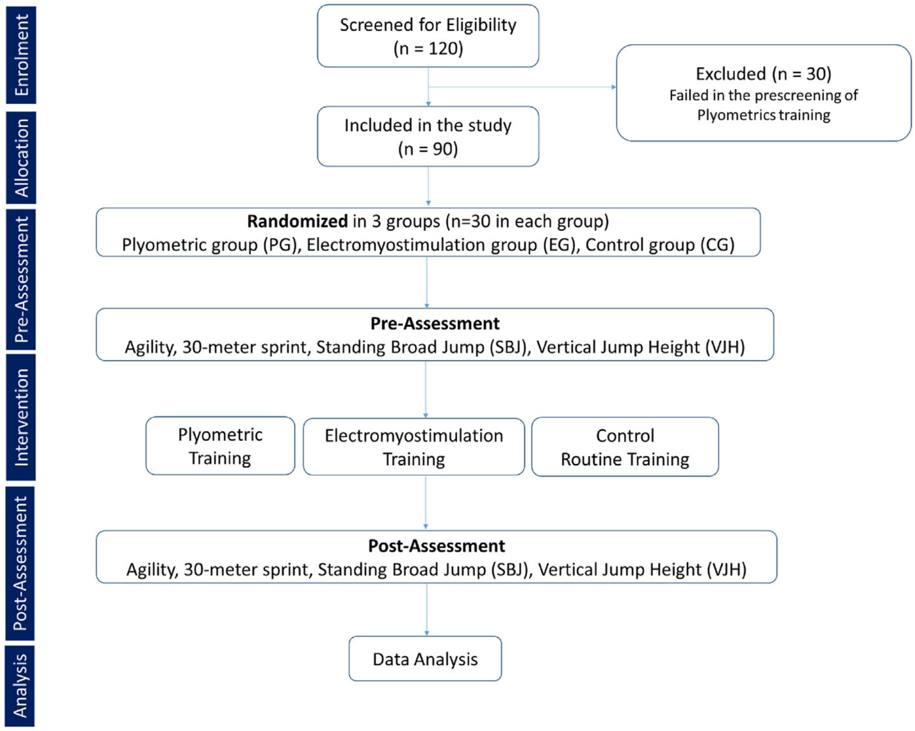

Fig. 1. Consort Chart of the study design.

Table 1
Plyometric training protocol.

Week	Training Volume (Foot contacts)	Plyometric Drills	Sets × reps	Training intensity
Week 1	90	Double leg hops	2 × 15	Low
		Single leg hops	4 × 5	Low
		Front cone hops	4 × 5	Medium
		Zig-zag hop	2 × 10	Low
Week 2	120	Standing long jump	5 × 6	Low
		Standing jump and reach	3 × 10	Low
		Side Cone hops	3 × 10	Medium
		Split jump	3 × 10	Medium
Week 3	120	Tuck jump	2 × 15	Medium
		Repeated long jump	3 × 10	Medium
		Repeated Vertical squat jump	3 × 10	Medium
		Box Shuffle	2 × 15	Medium
Week 4	120	Explosive sit-ups	3 × 10	Medium
		Explosive step-ups	3 × 10	Medium
		Box jump	2 × 15	Medium
		Single leg cone hops	3 × 10	Medium

Reps: Repetitions.

plyometric session lasted about 35 min, including 10 min of warm-up (jogging and dynamic stretching), 20 min of plyometric exercises, and 5 min of cool-down (jogging and static stretching). The players were under close supervision during the training session, and proper exercise technique was ensured to do each exercise. After each plyometric session, athletes were reminded not to perform any plyometric or strength training other than their plyometric program. This group continued its routine badminton practice and related training throughout the experimental phase.

Electromyostimulation

The electromyostimulation was given for four weeks (four sessions/week), and each session consisted of 16 min of the active duration. Electromyostimulation was applied over both lower limbs' quadriceps femoris and triceps surae muscles. The players were asked to sit on a mat with their back supported, and the knee flexed 60° (0° corresponds to full knee extension). The passive electrodes were placed on the proximal aspect of quadriceps femoris and triceps surae muscles close to their origin, and the active electrodes were placed on the motor points of both muscle groups. The stimulator generated biphasic symmetrical rectangular wave pulsed currents (120 Hz) with a pulse width of 400 μs. The contraction: relaxation time was set at 3:7 s (40% duty cycle). During each session of electromyostimulation, each muscle performed 48 contractions. The intensity was increased to moderate toleration, and varied between 20 and 50 mA. None of the subjects complained of discomfort or irritation from the stimulus. This group also continued its routine badminton practice and related training.

Control group

The players in the control group did not receive any supervised exercise protocol or any electrical stimulation. However, they continued their routine badminton practice and related training.

Testing evaluation

All players were assessed in three sessions. They were assessed with eligibility criteria, demographic characteristics and physical fitness evaluation on the first day. Then, they performed warm-up and testing procedures as a familiarization session. Outcome measures were measured sequentially with agility T-test, 30-m sprint test, standing broad jump (SBJ) and vertical jump height (VJH) test. On the second day, pre-intervention testing was assessed. Post-intervention testing was assessed after four weeks of intervention with warm-up and practice trials. Practice trials were given to each player to diminish the learning effect. Participants were encouraged with strong verbal commands to perform maximally and rapidly.

The agility T-test was used to determine the player's agility. Four cones were placed in a standard manner as mentioned in Fig. 2. On

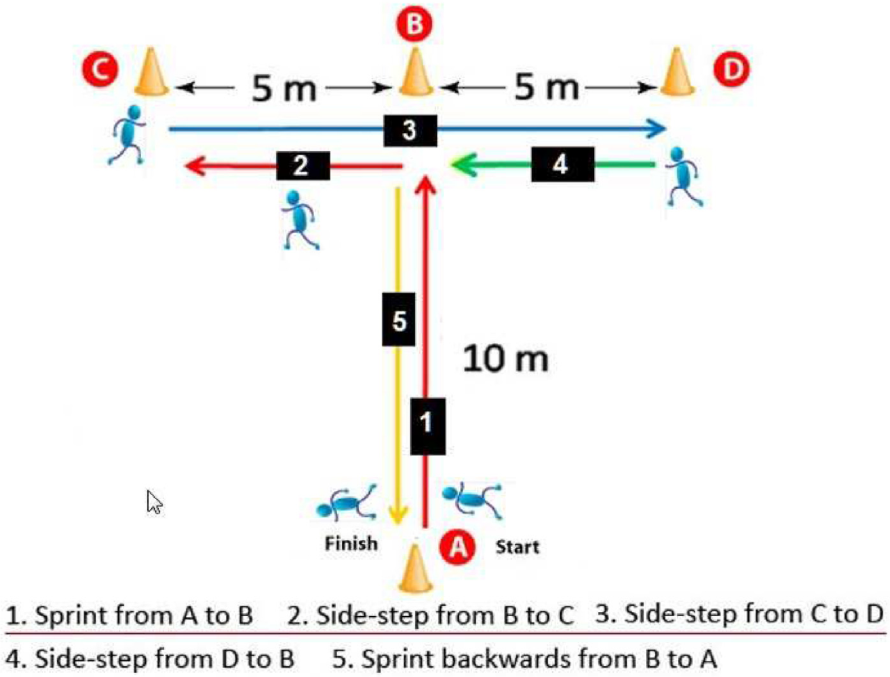

Fig. 2. Agility T-test; m: meter; the alphabet A, B, C and D refers to different cones placed from start to finish; the numerals 1 to 5 indicates the direction in the sequential manner.

command go, each player started sprinting 10 m from cone A to touch the base of cone B, followed by shuffling 5 m towards the left side to touch the base of cone C, followed by shuffling 10-m towards the right side to touch the base of cone D, followed by shuffling 5-m to the left to touch the base of cone B and sprinting back to the cone A. The total time to complete the circuit was measured using a stopwatch to the nearest 0.01 s. The best of three trials was used for analysis.

Thirty-meter sprint test was used for running speed. Players were allowed for a warm-up and total recovery time before actual testing. The front foot was placed on or behind the start line. With the tester whistle, the players started to sprint, and the time was recorded nearest to 0.01 s using a stopwatch as the players crossed the 30-m line. The best of three trials was used for analysis.

SBJ test was used to measure lower limb explosive power. The players stood with both feet on level ground with the point of the shoe at a marked line and arms by the sides. Players were asked to jump as far forward as possible. The measurements were taken in cm from the marked line to the point of heel contact. The best of three jumps was used for analysis.

Each player performed a VJH Test. The player stood side onto the wall, keeping both feet on the ground, reaching up with one straight hand and touching the wall with the tip of the middle finger marked with ink. Then they were asked to static squat down, jump as high as possible, and marked the wall with the tip of the middle finger. The best of three trials was used for analysis.

Statistical analysis

Statistical analysis was performed using SPSS Version 25.0. Before applying parametric tests, assumptions of normality were evaluated using a Shapiro-Wilk test. The data distribution for all variables at all levels was tested at a p-value > 0.05. One-way analysis of Variance (ANOVA) was used to determine differences in demographic characteristics and outcome measures among the three groups at baseline. Two (pre and post values) × three (interventions) ANOVA was used to find out the main effect (time and intervention effect) and time × intervention interaction. If the pre-intervention values showed a significant effect, then a two into three analysis of covariance (ANCOVA) was used, considering pre-values as covariates. In addition, one-way ANOVA was employed on the difference (between pre-and post-intervention values) for all the outcome measures. Further, paired t-test was used for each group to find out the difference between pre-intervention and post-intervention. A Bonferroni test was used for Posthoc multiple comparisons between the groups. The significance level was set at $p < 0.05$, and a confidence interval was set at 95%.

Results

The Badminton Player's characteristics in both PG and EG groups are provided in Table 2.

There was no significant change in the baseline observations of age, weight, height, BMI, years of experience and weekly training. On the

Table 2
Demographic characteristics of players and outcome measures at baseline.

Variables	PG ($n = 30$)	EG ($n = 30$)	CG ($n = 30$)	p-value
Age (years)	19.06 ± 1.33	18.26 ± 1.09	17.5 ± 0.52	0.065
Weight (kg)	61.46 ± 5.97	60.4 ± 1.91	56.4 ± 6.2	0.086
Height (m)	1.68 ± 0.03	1.72 ± 0.03	1.62 ± 0.03	0.071
BMI (kg/m^2)	21.59 ± 1.85	20.25 ± 1.17	21.26 ± 1.99	0.091
Gender (M/F)	12/3	14/1	11/4	–
Years of experience	8.06 ± 1.94	6.8 ± 1.26	7.1 ± 0.99	0.081
Weekly training (min)	181.33 ± 29.24	194.66 ± 42.4	164 ± 23.19	0.097
Agility (s)	11.43 ± 0.79	10.99 ± 0.57	11.99 ± 0.81	0.007*
30-m sprint (s)	4.95 ± 0.29	4.43 ± 0.24	4.56 ± 0.15	<0.001*
SBJ test (cm)	211.8 ± 36.9	228.53 ± 13.95	208.6 ± 16.41	0.108
VJH test (cm)	46.20 ± 7.22	53.80 ± 3.38	46.70 ± 4.13	0.001*

30-m sprint: 30-m sprint; PG: plyometric group; EG: electromyostimulation group; CG: control group; SBJ: Standing broad jump; VJH: Vertical jump height; kg = kilogram, m = meters, cm = centimeter; min = minutes; s = second; M = Male, F= Female; *: significant difference $p < 0.05$.

other hand, there was significant change in agility, 30-m sprint and vertical jump height between the three groups. The plyometric training significantly reduces the time required to complete the agility ($p = 0.007$) and 30-m sprint tests ($p < 0.01$). In addition, the plyometric training is beneficial for improving the SBJ ($p = 0.001$) and VJH tests ($p = 0.001$). Electromyostimulation resulted in a statistically significant difference in the distance moved by badminton players during SBJ ($p < 0.001$) and VJH tests ($p < 0.001$) (Table-3).

Agility was non-significant for time, intervention effect and time intervention effect. Thirty-meter sprint was found significant for intervention effect and time - intervention interaction ($p = 0.017$). SBJ test (cm) was found to be significant for the time and time-intervention effect. VJH test (cm) was significant for intervention effect and time-intervention effect.

There was no significant difference in the agility test between the groups. Further, 30-m sprints revealed a significant difference between PG with CG ($p = 0.001$) and EG with CG ($p = 0.003$). The difference in the mean of SBJ from pre to post intervention between the plyometric and control was significant (Table 4). The VJH was found to be significant for intervention effect ($p = 0.004$) and time-intervention ($p = 0.004$) interaction whereas the time effect was found to be non-significant. Posthoc comparison of VJH showed a significant change between CG vs PG ($p = 0.005$) and between CG vs EG ($p = 0.026$).

Discussion

The impact of electromyostimulation on agility is yet to be thoroughly studied but there was a significant difference in pre to post measurement. The improvement in agility by plyometric training was statistically significant and this result is in accordance with the previous studies. Heang et al. stated that six weeks plyometric training program can improve agility in badminton players.[15] Dimas et al. in their study stated that progressive plyometric training significantly improves lower limb muscle power influencing the agility of badminton players, which might be the reason for this study.[16] It is also well established that agility requires muscle strength and power to boost lateral velocity change.[17] When both the groups were compared with the control group there was no significant difference, which might be due to good sport specific training received by the participants.

In this study, a comparison of plyometric training and electromyostimulation was tested on agility, 30-m sprint test, standing broad jump (SBJ) and vertical jump height (VJH) test in 17–24 years male state-level badminton players. There was no significant difference between age, height and weight between all three groups. This study showed that four weeks of Plyometric and EMS had some improvement in 30-m sprint timing. Out of both the PG and EG groups, PG had significant improvement in comparison to the control group. This result is supported by many previous studies which have indicated that plyometric training due to the stretch-shortening process can improve sprinting ability.[3] Some authors found that after six weeks of training on the sand, plyometric improved the performance of a 20-m sprint distance.[8] Some found that increased running speed in soccer players after eight weeks of plyometric training.[3] The quality of the badminton-specific training regimen may explain the improvement in a sprint after only four weeks. Increasing muscle rate and speed with plyometric may also improve sprinting. Plyometric training did not change 30-m sprint time compared to EG. This study recommends using plyometric to improve sprint speed over electromyostimulation of lower limb muscles.

The result of this study related to sprint time enhancement was in contrast to the study done by Herrero et al. who found that EMS training alone could not improve sprint running. Wisloff et al. stated that maximal quadriceps femoris isokinetic torque and squat strength improvement through EMS might reduce sprint times.[18] Another study in this regard did not find any significant change in sprint time and velocity after three and five weeks of EMS training.[19] No growth in sprint speeds may be owing to the intricacy of running, which activates several muscles, and the athletes' technical competence. EG's sprint performance was not significantly better than PG or CG.

This study also showed improvement in lower limb explosive power (measured through standing broad jump test) for both plyometric training (6.92%) and EMS training (3.93%). Studies show EMS training increases explosive power. Post-testing with isometric whole-body EMS increased rectus abdominis maximal power by 67%. Speicher et al. found no significant power improvements in quadriceps femoris and biceps femoris with dynamic whole-body EMS. Both muscle groups improved in maximal power following two weeks of detraining with a test weight of 40% 1RM (+ 13% in quadriceps femoris and + 29% in biceps femoris). Maximal power can be increased by developing either force or speed.

Improvement in explosive power through plyometric training supports some previous studies. Chelly et al. found that force-velocity test data applied to identify peak power production in soccer players showed increases in absolute peak power and relative peak power to the body mass.[20] Plyometric training may increase power production through improvement in coordination and neuro-muscular adaptation.[21] Any increase in leg peak power by plyometric might be because of neuronal adaptations, selective activation of motor units, synchronization, selective activation of muscle and increased recruitment of motor units.[22]

Change in the rate of force development can be a possible reason for the gains in the VJH, as already reported in adults.[23] Improved coordination and synchronization of active muscle groups through enhancement of power transfer during the stretch-shortening cycle and transfer of energy for neuromuscular demands can be another cause behind it.[24] Chelly et al. got a significant improvement in squat jump height ($p < 0.01$) and countercurrent movement jump (CMJ) height relative to the control group after eight weeks of plyometric training in soccer players. They stated that plyometric training may improve jumping performance by increasing power production through improving coordination and neuromuscular adaptation.[6]

However, this finding of the study is in contrast to the study done by Sozbir who did not find any significant improvement in CMJ height after plyometric training for 6 weeks.[25] Many authors didn't get any significant improvement in VJH performance after plyometric training[26,27] and some even found a negative effect.[13] These dissimilarities might be due to the different fitness levels of the participants (trained vs untrained).

The EG's VJH improved significantly ($p < 0.001$) compared to the CG, corroborating prior results. Basketball players improved their squat jump by 14% at week four ($p < 0.01$) and 17% at week eight ($p < 0.01$).[28] They

Table 3
Results of paired *t*-test between pre and post intervention for given outcome measures.

Variables	Pre-Intervention Mean ± *SD*	Post-Intervention Mean ± *SD*	Paired *t*-test *p*-value
Agility -test (s)			
Plyometric	11.43 ± 0.79	11.23 ± 0.87	0.007*
Electromyostimulation	10.99 ± 0.57	10.96 ± 0.56	0.541
Control	11.99 ± 0.81	11.98 ± 0.6	0.915
30-m sprint test (s)			
Plyometric	4.95 ± 0.29	4.76 ± 0.27	< 0.001*
Electromyostimulation	4.43 ± 0.24	4.4 ± 0.27	0.401
Control	4.56 ± 0.15	4.57 ± 0.22	0.832
SBJ test (cm)			
Plyometric	211.8 ± 36.9	226.46 ± 37.16	0.001*
Electromyostimulation	228.53 ± 13.95	237.53 ± 14.16	0.001*
Control	208.6 ± 16.41	210.3 ± 15.68	0.215
VJH test (cm)			
Plyometric	46.2 ± 7.22	48.26 ± 7.79	< 0.001*
Electromyostimulation	53.8 ± 3.38	55.93 ± 3.57	< 0.001*
Control	46.7 ± 4.13	47.4 ± 3.97	0.045*

Note: s = second, cm = centimeter; PG: plyometric group; EG: electromyostimulation group; CG: control group; SBJ: Standing broad jump; VJH: Vertical jump height; *SD*: Standard deviation; *p*: level of significance; *: significant difference $p < 0.05$.

Table 4
Results of ANOVA or ANCOVA for given outcome measures.

Variables	PG	EG	CG	Time (T) effect	Intervention (I) effect	T × I Interaction	Post hoc pairwise comparison		
	(*n* = 30)	(*n* = 30)	(*n* = 30)				PG vs CG	EG vs CG	PG vsEG
	Mean ± *SD*	Mean ± *SD*	Mean ± *SD*	*p*-value	*p*-value	*p*-value	*p*-value	*p*-value	*p*-value
Agility T-test (s)									
Pre-intervention	11.43 ± 0.79	10.99 ± 0.57	11.99 ± 0.81	0.189	0.067	0.067	0.082	1	0.457
Post-intervention	11.23 ± 0.87	10.96 ± 0.56	11.98 ± 0.6						
Difference	0.19 ± 0.24	0.03 ± 0.2	0.01 ± 0.28				0.188	1	0.2
Mean change (%)	1.74 ↓	0.27 ↓	0.08 ↓						
30-m sprint test (s)									
Pre-intervention	4.95 ± 0.29	4.43 ± 0.24	4.56 ± 0.15	0.642	0.017*	0.017*	0.014*	1	0.118
Post-intervention	4.76 ± 0.27	4.4 ± 0.27	4.57 ± 0.22						
Difference	0.18 ± 0.09	0.03 ± 0.14	−0.007 ± 0.1				0.001*	1	0.003*
Mean change (%)	3.83 ↓	0.67 ↓	0.21 ↑						
SBJ test (cm)									
Pre-intervention	211.8 ± 36.9	228.53 ± 13.95	208.6 ± 16.41	<0.001*	0.075	0.01*	1	0.082	0.416
Post-intervention	226.46 ± 37.16	237.53 ± 14.16	210.3 ± 15.68						
Difference	14.67 ± 13.2	9 ± 8.22	1.7 ± 4.02				0.007*	0.226	0.362
Mean change (%)	6.92 ↑	3.93 ↑	0.08 ↑						
VJH test (cm)									
Pre-intervention	46.2 ± 7.22	53.8 ± 3.38	46.7 ± 4.13	0.611	0.004*	0.004*	0.005*	0.026*	1
Post-intervention	48.26 ± 7.79	55.93 ± 3.57	47.4 ± 3.97						
Difference	2.07 ± 0.79	2.13 ± 1.12	0.7 ± 0.94				0.004*	0.003*	1
Mean change (%)	4.45 ↑	3.95 ↑	1.49 ↑						

Note: s = second, cm = centimeter; T: Time, I: Intervention: TxI: Time × Intervention Interaction; PG: plyometric group; EG: electromyostimulation group; CG: control group; SBJ: Standing broad jump; VJH: Vertical jump height; *SD*: Standard deviation; ↑: increase; ↓: decrease; p: level of significance; *: significant difference ($p < 0.05$).

blamed electrical stimulation-induced neuronal adaptation of fast-twitch fibers. Henneman's size theory predicts EMS will stimulate motor units differently.[29] EMS activates the biggest motor neurons (innervating type-2 fibers) first and to a larger extent than voluntary contractions.[30] Three factors affect the order of motor unit activation during EMS.

According to one study, Fast-twitch fibers improve VJH and CMJ performance. The influence of fiber type is more complex in functional tasks like jumping.[31] Malatesta et al. found that four weeks of isometric EMS training improved VJH. After acute EMS, some writers reported an increase in vastus lateralis lactate production.[9] Electrically induced activity has a larger anaerobic ATP cost than voluntary exercise, hence EMS training may increase VJH.[9] In our study, EMS training improved VJH similarly to Plyometric training ($p < 0.001$).

Limitations

The subjects were not divided based on their experience, level of playing or gender as that can impact the results. The history of past training was also not collected, or divided in this research. The long-term effect after veining off the training was not studied. The energy expenditure for the study groups was not evaluated making it a limitation of this study. As a result, changes in energy consumption, exercise, and training might contribute to explaining disparities.

Conclusions

Based on the results of the present study, it is concluded that four weeks of Plyometric training added to general sports training is more effective than electromyostimulation training added to general sports training in enhancing sprinting ability and agility of badminton players. This study also concludes that both four weeks of Plyometric training and four weeks of electromyostimulation training have a significant effect, when added to general sports training, in enhancing VJH performance in badminton players.

Practical application

Plyometric training has been used by coaches and athletes in their training protocol as a performance and fitness-enhancing tool. From the practical point of view, we can suggest EMS training to enhance vertical jump performance without interfering with sport-specific badminton training. EMS training can provide an advantage over other forms of physical training for improving vertical jump ability when the time available for physical training is limited. Indeed, ~64 min of EMS per week during four weeks along with general sports training resulted in significant improvement in vertical jump ability for subjects in this study, whereas other physical training protocols usually require more than 64 min per week. EMS training can be used throughout the season in two ways. Firstly, it can be used in the early season as, without any interruption in badminton training, it is enhancing vertical jump performance. Secondly, players' performance can be maintained at a high level throughout the season utilizing badminton training only.

Authors' contribution

Manibhadra Panda contributed to the article's conception, design, research, and writing. Ankita Sharma also helped in the data collection phase of the project, data interpretation, data gathering, and writing. Priyanka Sethi was involved in the article's conceptualization, design, and data interpretation. Moattar Raza Rizvi assisted in the statistical analysis of study data, the interpretation of data, the authoring, and dissemination of the scientific work. Irshad Ahmed contributed to the creation of the literature review, writing results and research publications. Sunita Kumari contributed in conceptualization, data interpretation and critical review of the article.

Submission statement

All authors have read and agree with manuscript content. This manuscript will not be submitted for review or publication elsewhere while it is being reviewed for this journal.

Ethical approval statement

Ethical approval was obtained from the Department Ethical Committee at Faculty of Allied Health Sciences in accordance to Ethical Principles for Medical Research involving human with reference No: MRIIRS/FAHS/DEC/2021-S17 dated 12th April2021. Written Informed consent was obtained from each participants explaining the risk and benefits of the study.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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