

Effect of Pilates on Lower Limb Strength, Dynamic Balance, Agility and Coordination Skills in Aspiring State Level Badminton Players

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ABSTRACT

Introduction: Badminton, considered as one of the fastest racquet sports in the world requires excellent strength, dynamic balance, quick reflexes and coordination. Pilates is a form of training that focuses on strengthening core muscles of body and achieving mind body connection. Traditionally Pilates has been used for posture training and enhancing core strength. Now-a-days it is increasingly being incorporated into athletic training programmes for injury prevention and enhancing performance.

Aim: To evaluate the efficacy of Pilates on lower limb strength, dynamic balance, agility and coordination skills in aspiring state level badminton players.

Materials and Methods: Forty male aspiring badminton players in the age group of 17-28 years were included in this experimental study and randomly divided into two groups- Experimental and control group with 20 players in each group. Experimental group (Group A) received Pilates training along with conventional training whereas control group (Group B) was

given conventional training only that included warm up, cool down and sports specific exercises. All players were evaluated for lower limb strength, agility, dynamic balance and upper limb coordination with Vertical Jump Test, 10 m Shuttle Run Test, Star Excursion Balance Test and Hand-Eye Coordination Test respectively. Both groups received training for 5 weeks twice a week, for 60 minutes. ANOVA and Student t-test was used to compare the intergroup difference in the analysis of the data collected for all variables at 1st week, 3rd week and last day of the 5th week of intervention.

Results: Both groups improved significantly at the end of 5th week but experimental group showed highly significant difference for lower limb strength, dynamic balance, agility and coordination as compared to Control group ($p < 0.05$).

Conclusion: Pilates is an effective method for improvement in lower limb strength, agility, dynamic balance and coordination skills in badminton players.

Keywords: Athletic performance, Core stability, Fitness, Star excursion balance test, Shuttle run test

INTRODUCTION

Badminton happens to be one of the most popular and most played sports in India and worldwide. Among the indoor games, badminton occupies a place of pride both as an individual as well as team sports [1]. Sports performance is based on a complex variety of factors, which include physical (general and specific conditions), psychological (personality and motivation), sociological and physical factors [2]. Badminton is a complex physically enduring sport that requires an extensive amount of core strength as well as upper and lower body strength to produce powerful smashes, agility, good balance and coordination during rapid postural movement around the court.

Pilates exercises or Joseph Pilates method began developing his exercise system over a period of approximately 50 years in early 1900s [3]. It is a whole body conditioning programme which was initially used for managing low back pain and improving balance in elderly. Now-a-days it is used for posture correction and fitness training. Pilates based exercise works on the principles of trunk stability, also known as "core stability". "Core is described as a box, with the abdominals (transversus) in front, paraspinals (multifidus) in back, diaphragm in top and pelvic floor at the bottom". Pilates is a popular form of exercise training programme which includes series of stretching and strengthening exercises with proper trunk control and breathing. It is associated with numerous health benefits like improved muscle strength, tone, flexibility, coordination, lung volumes and capacities through deep breathing [4,5].

Pilates training method is based on 6 principles that are Centering (i.e., focussing on tightening the power house), Concentration, (i.e., mental focus and attention while performing exercise), Control (i.e., postural management while performing the exercise), Precision (i.e., accuracy of exercise techniques), Flow (i.e., smooth transition of movement within the exercise sequence), Breathing in coordination with the exercise [6]. Pilates improves posture, balance, increase core strength, peripheral mobility, which may be helpful for improving athletic performance [3].

The main purpose of pilates is to organise the mind, body, and breathe to build up sleek and strong abdominal muscles and a strong and agile back. It improves flexibility, tonicity, strengthens core muscle groups, enhances body awareness, prevents injury, develops posture and balance, and comfort of movement through daily life. Pilates gives equal importance to strengthening-body conditioning and the mind [7].

Conventional exercise programs are commonly thought to involve those exercises that target specific muscles or muscle groups that are recruited during sports specific technique, so as to enhance their strength during performance. In badminton, the players and coaches follow some of the conventional training items to improve different aspects of physical fitness and psychological health of sports person through different training programmes [7]. Warm up, flexibility exercises, endurance exercises and sports specific exercises for badminton are included in conventional training of badminton players. Sports specific training is done for improving fitness and performance in sports.

Agility, one of the essential components of physical fitness can be described as ability to rapidly change direction without losing balance. Strength, speed and coordination are essential components of agility. In badminton, agility is needed to reach the approaching shuttle as well as for rapid changes in directions within small duration of time that are needed during the process of game [8].

Lower body strength is essential in sports for enhancing balance, agility and for generating power needed for explosive movements. Largest muscles located in the lower body (gluteal, abductors, adductors, hamstrings, quadriceps) are essential in movements needed for day today or sporting activities. Lower body strength plays an important role in badminton as it helps in producing better and faster footwork. The strong lower body allows stopping and changing direction quickly and also improves speed while moving around in badminton court. Also stronger lower limb muscles helps in producing stronger smashes by transferring energy from legs to upper body [9].

Dynamic balance requires moving a stable postural set over the base of support. Badminton involves rapid postural movements around the court which include quick and repetitive movements like jumping and squatting. Dynamic balance is crucial fitness component to prevent lower limb injuries that can result because of poor balance [10].

Coordination is the capability to perform a sequence of movements rhythmically smoothly and accurately. It involves the sense of body, muscular contraction and joint movement of the body. All racket sports require the coordination of eye, hand, foot and ball. A successful badminton player requires a good physical fitness and sense of coordination [11]. English T et al., studied the effect of Pilates exercise on trunk and postural stability and throwing velocity in college baseball pitchers. They found significant effects in improving core strength, balance and throwing speed in college baseball pitchers [12]. A study has found positive effects of Pilates on balance, reaction time, muscle strength, number of falls and psychological parameters in 65 plus-years old women [13]. Emery K et al., studied the effects of a Pilates training program on arm-trunk posture and movement. It was found that Pilates exercise training was effective in improving the spinal alignment and core muscle strength [14]. Rydeard R et al., did a study on Pilates-Based Therapeutic Exercise, in Subjects with Nonspecific Chronic Low Back Pain and Functional Disability. It was found that Pilates training which train to stabilize the lumbo-pelvic region has a significant effect in decreasing low back pain and disability [15].

None of the previous studies till date have studied the effect of Pilates training on various parameters of physical fitness required in badminton players. Most of the studies have studied effect of pilates in healthy population. Very few studies have focused on the effect of pilates in sports that require excellent strength, agility and coordination. This work intends to develop novel ways of promoting different training program utilisation that would have the potential to revolutionise the improvement of performance in badminton players.

The research hypothesis, says that there would be a significant difference between Pilates exercise group and conventional exercise group in aspiring state level badminton players. The aim and objectives of the current study was to compare the effect of Pilates exercises along with conventional exercises with conventional exercises alone on lower limb strength, dynamic balance, agility and coordination in aspiring state level badminton players.

MATERIALS AND METHODS

This experimental study was carried out at D'Valls badminton school, Gurugram. The study was approved by the ethical research committee of SGT University. Ref. No. SGTU/FOP/2018/37. The data collection for study commenced in the month of March 2018 after ethical clearance in February 2018 and continued till July 2018.

Data compilation, analysis and report writing took around 4 months (till November 2018). A sample size of 40 was calculated using G Power. Power of the study is 0.95.

Players who fulfilled the inclusion and exclusion criteria participated in the study. The inclusion criterion for the study was: the age group between 17-28 years, players who were playing badminton for more than 2 years with no history of any injury in past 6 months. Players who were excluded from the study were those having any musculoskeletal problem that decreased the compliance of the players to participate in the study and any medical condition that would impair their playing activities. The whole procedure of the training program was explained to the players and written informed consent was taken from all the players.

Details like name, age, number of playing years, history of any previous injuries, and any medical condition of the player was recorded in the evaluation performa.

Players who fulfilled the inclusion and exclusion criteria were divided into two groups by simple random sampling method i.e., group A included 20 players which received Pilates training along with conventional exercises (Experimental group) and group B included 20 players that received conventional exercises only (Control group). Measurements were taken for age, height, weight and Body Mass Index (BMI) for all subjects. All players underwent baseline assessment for agility, lower limb strength, dynamic balance and hand eye coordination.

1. Agility was measured by 10 m shuttle run test [16]

The objective of this test is to assess the athlete's ability to accelerate between marked lines and to rapidly change direction. It required a slip-proof floor, 4 cones, a stopwatch and three sponges were used to perform the test. The players performed warm up for 10 minutes. Two parallel lines were drawn on the floor 10 m apart. The players were asked to run as fast as possible from the starting line to the other line and return to the starting line, crossing each line with both feet every time. This was performed twice; covering a distance of 40 m (4×10 m). The stopwatch was stopped when the player crossed the end line with one foot. Time in seconds was noticed.

2. Lower limb strength was measured by vertical jump test [16]

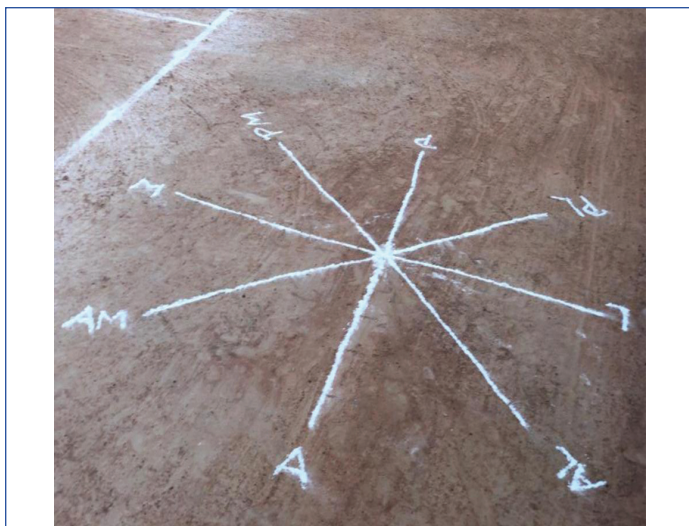
The players were instructed to put chalk on the finger tips to mark on the wall. Keeping both feet in contact with the ground, they stood side on to a wall and reached as high as possible with the hand closest to the wall and marked it with finger tips. This distance is called standing reach height (P1). Players were then instructed to stand little away from wall and jump as high as possible in vertical direction using both arms and legs and again mark the wall with chalk on their fingertips (P2). The difference in the distance between 2 points (P1 and P2) was recorded as the score.

3. Dynamic balance was measured by Star Excursion Balance Test (SEBT) [17]

The SEBT was performed with the player standing at the center of a grid placed on the floor, with 8 lines extending at 45° increments from the center of the grid. The 8 lines were labeled according to the direction of excursion relative to the stance leg: Antero-lateral (AL), Anterior (A), Antero-medial (AM), Medial (M), Postero-medial (PM), Posterior (P), Postero-lateral (PL), and Lateral (L). To perform the SEBTs, the player maintained a single-leg stance while reaching with the opposite leg as far as possible. The player lightly touched the farthest point possible on the line with the most distal part of the reach foot then returning to a bilateral stance while maintaining their balance. The distance was measured from the center of the grid to the touch point with a tape measure in centimeters [Table/Fig-1].

4. Hand and eye co-ordination test [18]

This test was used to measure the co-ordination between eye and hand. One line was marked two meter away from the wall. Subject started the test from starting line. On the signal of start subject



[Table/Fig-1]: Star excursion balance test.

hits/threw the ball against the wall and catches the ball with the other hand, after he catches it he throws the ball with that hand and catches it with the other hand. This process continued for the 30 second. After 30 seconds, the timer gives the signal stops and the subject stopped and the numbers of correctly made catches were recorded.

Procedure: Players in group A received Pilates training in addition to conventional exercises which included warm-up followed by badminton specific training. The session ended with cool down exercises. Group B received conventional exercises only. Both groups received intervention for 60 minutes twice a week for 5 consecutive weeks, with a total of 10 sessions under the supervision of the therapist [Table/Fig-2].

Exercise program	Pilates exercise program (Group A)	Conventional exercise program (Group B)
Warm up	10 minutes	15 minutes
Pilates exercises	25 minutes	-----
Badminton-specific training program	15 minutes	35 minutes
Cool down	10 minutes	10 minutes
Total time	60 minutes	60 minutes

[Table/Fig-2]: Training programme for Group A and Group B.

Group A Protocol

Pilates training included 7 exercises. Detailed protocol is explained in [Table/Fig-3,4].

S. No.	Exercises	Equipment	Repetitions×Sets
1.	Standing footwork	Mat	8×3
2.	Hundreds	Mat	8×3
3.	Articulating bridge	Mat	8×3
4.	Rolling like a ball	Mat	8×3
5.	Plank	Mat	8×3
6.	Side plank	Mat	8×3
7.	Reverse plank	Mat	8×3

[Table/Fig-3]: Pilates exercises program. I, II and III Weeks Pilates Exercise Training.
Rest between Exercises:- 10-20 Seconds
Rest between Set of Exercise:- 45-60 Seconds

Following Pilates exercises were included:

Standing footwork [7]

It focuses on lower body strengthening, flexibility and core stability. It strengthens the muscles of the legs and pelvis, increased hip flexibility, strengthened the core, and improves balance. Breathing instructions for this exercise were as follows: subjects inhaled after beginning the movement and exhaled when performing the movement. This

S. No.	Exercises	Equipment	Repetitions×sets
1.	Standing footwork Raised heels and maintained "v" shape	Mat	15×3
2.	Hundreds with knee straight	Mat	15×3
3.	Articulating bridge Extend leg alternatively	Mat	15×3
4.	Rolling like a ball Grasp the ankles and pull into a tighter ball.	Mat	15×3
5.	Plank Extend one leg at a time	Mat	15×3
6.	Side plank Raised hand at 90°	Mat	15×3
7.	Reverse plank alternating leg extensions on each leg	Mat	15×3

[Table/Fig-4]: Pilates exercises program. IV and V Week Pilates Exercise Training.
Rest between Exercises:- 10-20 Seconds
Rest between Set of Exercise:- 45-60 Second

exercise was repeated ten times. The subject began the training session while in Pilate's posture ("V" stance). While maintaining the Pilates "V", the subjects were instructed to rise onto their toes as far as possible while keeping the heels together. Then they lowered to the ground while maintaining a neutral spine. Maintaining proper Pilate's posture, the subject was then instructed to perform a plié (bending at the hips and knees). The subjects were given verbal feedback regarding corrections and progress [Table/Fig-5].



Standing Footwork

[Table/Fig-5]: Pilates exercise.

2. Hundreds [7]

Players were asked to lie in supine lying position with arms at his sides and neutral pelvis. The subjects were instructed to curl their head and shoulders off the floor. The arms then move up and down slowly, initiating the movement from shoulder joint. The subjects inhaled for a count of five and exhaled for a count of five [Table/Fig-6].

3. Articulating bridge [7]

Players were asked to lie in supine lying with feet flat on floor (knee bent) with arms at the side of the body. Players were asked to draw the stomach inward. Then they were instructed to begin peeling the vertebra from the floor one at a time beginning with tail bone. The movement ended when it reached the shoulder blade. The subjects then returned to the starting position. Subjects inhaled while preparing for the movement and exhaled as they lifted their torso. Then inhaled at top of position and exhaled while lowering [Table/Fig-6].

4. Plank [7]

Players were in kneeling position on the mat on all fours with hands aligned directly beneath the shoulder and knees directly beneath the hips. While keeping the shoulders wide and flat, the subjects lifted into a push up position by placing one leg at a time on the

floor behind him. While maintaining body alignment the subjects extended one leg at a time [Table/Fig-6].

5. Reverse plank [7]

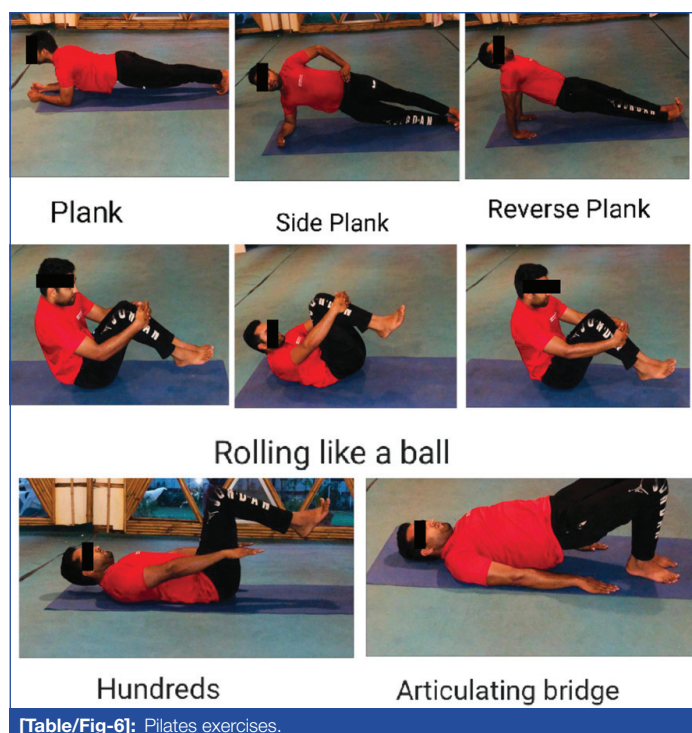
The subjects began by sitting with their arms behind them. Weight was on the hands with the fingers pointing at the heel. The subject then lifted his torso and pelvis into plank position. Then they rose onto one leg at a time without losing proper body alignment 3 times with 5 alternating leg extensions on each leg. The subjects inhaled to prepare for movement, exhaled as they lifted the torso upward, inhaled at the top position and exhaled while lowering pointing at the heel [Table/Fig-6].

6. Side plank [7]

The subjects sat on the side of his hip with the legs extended slightly in front. They were then instructed to cross the top leg over the bottom, resting on ball of his foot. The hand was placed on the floor aligned comfortably with the shoulder. The subjects then lifted their hips off of the floor in the movement and swept their top arm upwards. The subjects then allowed the body to rest on the lower hand and foot. Ribs were directly above the pelvis and the hip square with the body. This position was held for few seconds and then lowered to the floor maintaining body alignment [Table/Fig-6].

7. Rolling like a ball [7]

The subjects sat near the front of the mat with the knees bent and feet flat on the mat. They grasped their legs behind each knee and brought their chin toward their chest. The shoulders were down and the elbows positioned up away from the body. The subjects rolled backwards on their shoulder blades. The subjects then rolled back-up and balanced on the tailbone without letting their feet touch the floor, while keeping the same body position throughout the movement. The subjects inhaled while rolling back and exhaled when returning. The progression for this exercise was to grasp the ankles and pull into a tighter ball [Table/Fig-6].



[Table/Fig-6]: Pilates exercises.

Group A additionally received conventional training programme mentioned below.

Group B Conventional Training Protocol

Warm up included light exercises like walking, jogging and stretching.

Badminton-Specific Training Program

- Training schedule 1: Footwork Shadow stepping, full-field corner for 35 seconds in 8x8 again, a total of 6 sets, sets of 1-minute rest breaks. Total time: 20 minutes of intervention.
- Training schedule 2: Station training included rope skipping, jumping work, multi-shuttle, forward and backward court stepping training, 60% load at each station, a total of 5 sets of 20 seconds at each station, 1-minute rest break between each set. Total time 15 minutes.
- Training schedule 3: Strike training included clear, drop, high smash, 20 balls feeding training, continuous backcourt spike the ball thrown 20 kinds of work for each shot, 2 minutes rest interval between each shot. Total time 20 minutes of intervention.
- Training schedule 4: Drill work, stroke training as stroke types combined (Front, middle and back strokes made in the courts), 30 seconds loads, a total of 12 sets, 10 seconds rest period between each set. Total time 15 minutes of intervention.

Cool down- The session ended with cool down exercises, which consisted of following exercises: walk briskly/jogging, breathing and stretches to help recovery, prevent injury and soreness.

Data Collection

Readings were taken for Lower limb strength, agility, dynamic balance, and coordination skill by Vertical Jump test, Shuttle run test, Star excursion balance test and hand eye coordination tests respectively on 1st day of intervention and last day of 3rd and 5th week.

STATISTICAL ANALYSIS

The data was analysed by using the software package SPSS 24 for window version. Mean and standard deviation of all the variables were calculated. The level of significance was set at $p < 0.05$. ANOVA and Student t-test was used to compare the inter-group difference in the analysis of the data collected for all variables.

RESULTS

Mean comparison of age, height, weight and BMI was done for players in both the groups. Between group analysis showed that there was no significant difference in means of age, height, weight, and BMI of the players in both group $p > 0.05$ [Table/Fig-7].

Variables	Pilates group	Conventional group	t-value	p-value
Age (years)	19.70±2.44	20.45±1.64	1.15	0.257 ^{NS}
Weight (kg)	55.85±6.43	58.65±5.67	1.46	0.152 ^{NS}
Height (cm)	166.85±8.84	169.85±5.96	1.26	0.216 ^{NS}
BMI (kg/m ²)	20.14±1.56	20.02±1.43	0.253	0.802 ^{NS}

[Table/Fig-7]: Mean comparison of Age, Weight, Height and BMI.

p-value < 0.05 or .001 (significant or highly significant respectively)

p-value > 0.05 (non-significant)

NS: Non significant

The result of the study revealed that lower limb strength in group A showed 60% improvement at the end of 5th week and group B showed 20% improvement at the end of 5th week. Group A (experimental group) showed highly significant improvement by 40% as compared to group B $p < 0.001$ [Table/Fig-8].

Lower limb strength	Pilates group	Conventional group	t-value	p-value
Baseline	32.20±3.04	31.55±1.96	2.02	0.060 ^{NS}
3 rd Week	47.10±3.97	33.35±2.21	13.53	0.027*
5 th Week	53.45±4.90	35.00±1.96	15.64	0.001**

[Table/Fig-8]: Mean comparison of lower limb strength between the groups.

p-value < 0.001 (Highly significant)

*p-value < 0.05 (*Significant)

p-value > 0.05 (not significant)

NS: Non significant

The between group analysis for dynamic balance for both lower extremities (dominant and non dominant) in all four components (anterior, medial, posterior, lateral) as measured by star excursion balance test showed that there was a highly significant improvement seen in Experimental group as compared to Control group at 5th week, $p < 0.001$ [Table/Fig-9].

Dynamic balance	Groups	Mean±SD baseline	Mean±SD 3 rd week	Mean±SD 5 th week	t-value	p-value
Anterior component	Pilates Conventional	2.26±0.19 2.24±.18	3.38±0.10 2.32±.14	4.76±0.9 2.39±0.9	13.31	0.001**
Medial component	Pilates Conventional	1.66±0.13 1.65±0.15	2.74±0.11 1.74±0.11	3.69±0.13 1.84±0.7	8.432	0.001**
Posterior component	Pilates Conventional	1.82±0.18 1.79±2.7	3.35±.11 1.89±0.11	4.56±0.11 1.94±0.6	7.052	0.001**
Lateral component	Pilates Conventional	2.17±0.15 2.15±0.14	3.31±0.9 2.16±0.9	4.40±0.9 2.26±0.9	17.81	0.001**

[Table/Fig-9]: Mean comparison of dynamic balance between the groups.

p-value <0.001 (Highly significant)

*p-value <0.05 (*Significant)

p-value >0.05 (Non-significant)

The result of this study revealed that agility in group A showed 60% improvement at the end of 5th week and group B showed 25% improvement at the end of 5th week. But group A (Experimental group) showed highly significant improvement by 35% as compared to group B $p < 0.001$ [Table/Fig-10].

Agility	Pilates group	Conventional group	t-value	p-value
Baseline	12.25±1.12	12.20±1.15	0.139	0.890 ^{NS}
3 rd week	8.10±4.81	10.10±4.24	5.43	0.033*
5 th week	4.80±0.77	9.10±0.88	16.71	0.001**

[Table/Fig-10]: Mean Comparison of agility between the groups.

**p-value <0.001 (Highly significant)

*p-value <0.05 (*Significant)

p-value >.05 (**not significant)

NS: Non significant

The result of our study also revealed that coordination in group A showed 62% improvement at the end of 5th week and group B showed 30% improvement at the end of 5th week. But group A (experimental group) showed highly significant improvement by 32% as compared to group B $p < 0.05$ [Table/Fig-11].

Co-ordination	Pilates group	Conventional group	t-value	p-value
Baseline	14.60±1.12	14.00±1.15	0.972	0.337 ^{NS}
3 rd week	22.15±3.39	16.60±1.76	6.50	0.027*
5 th week	28.10±2.49	18.25±1.77	14.41	<0.001**

[Table/Fig-11]: Mean comparison of coordination between the groups.

p-value <0.001 (Highly significant)

*p-value <0.05 (*Significant)

p-value >.05 (not significant)

NS: Non significant

The between group analysis for agility, lower limb strength, and coordination using unpaired t-test showed that there was a significant difference between both the groups at 3rd and 5th week with more significant improvement seen in Experimental group i.e., Group A as compared to group B $p < 0.001$.

DISCUSSION

This study aimed to find the effect of Pilates exercise training on dynamic balance, lower limb strength, agility and coordination in state level aspiring badminton players. The players in this study had similar baseline values for age, height, weight and BMI.

The results of the study revealed that although both groups improved significantly at the end of the 5th week but Group A which performed Pilates exercises in addition to Conventional exercises brought better results with respect to improvement in lower limb strength as measured by vertical jump test, agility as measured by 10 m

shuttle run test, dynamic balance as measured by star excursion balance test and coordination measured by hand-eye coordination test compared to control group (Group B) which performed only conventional exercises.

Results of the study are similar to study by Yadav P et al., [19]. A pilot study was done on the efficacy of Pilates on agility and coordination skills in badminton players. It was concluded that there was a significant improvement in agility and coordination skills as measured by shuttle run test and hand eye coordination test by 41% and 63% respectively after an intervention of 5 weeks. The study concluded that Pilates training can enhance the control of trunk movement and improves the neuromuscular coordination of movements [19].

Lotfy S et al., studied the effect of Pilates on lower limb strength, jump performance and biological efficiency. It was concluded that Pilates training was highly effective in improving muscle ability (12.08%), jump height (12.58%), and biological capacity (12.86%) which might be due to biological efficiency and kinetic chain activities. They concluded that Pilates improves trunk muscle strength which improves motor coordination of limbs and hence motor performance. In any athletic activities, the players spontaneously hold their breath, which could affect their performance by reducing the air entry and therefore reducing the oxygen uptake and energy. One of the principles of Pilates is breathing control which makes awareness of one's own breathing during dynamic activities, which would enhance the performance by increasing air entry and therefore increases the oxygen uptake and energy. Pilates enhance biological capacity as there is increased oxygen supply to lungs and muscles by enhancing passage of oxygen through them [20].

The proposed mechanism for hand eye coordination improvement in Pilates group might be due to kinetic chain activities. When core stability is attained, the local group of core muscles gives stability to the mobility of the distal segments and the global group of core muscles increases the moment arm for lower limb movements, generate and transfer the forces from lower limb to upper limb and vice versa [21].

Results of this study are in accordance with results of study by Anitha A et al., which found strong positive correlation ($r=0.8$) between hand eye coordination and core muscle strength in non-athletes with low back pain. It was suggested that core forms a strong base on which strong and smooth movements of trunk and upper limb can be performed [22].

Johnson EG et al., found the effects of Pilates-based exercise on dynamic balance in healthy adults. The 5-week Pilates-based exercise session improved core stability and subjects became more kinesthetically aware of how to reduce faulty movement patterns, resulting in improved motor control. He concluded that ten sessions of a Pilates based exercise improved dynamic balance as measured by the Functional Reach Test in healthy adults [23].

The statistical findings of study by Yeole UL et al., on the effect of core strengthening on dynamic balance and agility in badminton players showed that compared to group that performed conventional exercises, Pilates training group had significant improvements in agility, core strength, neuromuscular coordination and dynamic balance at the end of 4 week of training [10].

The result of our study is consistent with the findings of the study by Shavikloo J et al., [24]. They concluded that 6 week Pilates training programme was more effective than conventional training in improving anterior, postero-lateral and postero-medial components of dynamic balance as measured by Y balance test in futsal players. Pilates training resulted in enhanced stability of vertebral column, neuromuscular coordination and hence dynamic balance [24].

In any of sporting activities, the performance is influenced by the psychological status of that athlete. Pilates exercises also

concentrate on the mind and body coordination. It can reduce anxiety and enhance athletic performance. The Pilates group had much significant improvement than control group because the regular use of Pilates exercise led to strengthening of abdominal and core muscles, flexibility of truncal muscles and increased the biological capacity efficiency by breathing control [25].

LIMITATION

The limitation of the study is small sample size and limited age group because of which results cannot be generalised. Also, female badminton players were not included in the study, so any gender specific differences in the results and associated factors could not be studied.

FUTURE RECOMMENDATIONS

Study can be done on a larger sample size and long term effects of Pilates can be studied. Long term effects on strength, agility, balance and coordination can be studied. Effect of Pilates on sports performance and incidence of injuries can be studied. Effect of Pilates on other physical fitness variables like speed, reaction, Cardiopulmonary fitness can also be studied.

CONCLUSION

The results of the study showed that physical fitness components i.e., lower limb strength, agility, dynamic balance and hand eye coordination showed significant improvement in the Experimental group that performed Pilates training along with conventional exercises as compared to the control group that performed conventional exercises only. So it is concluded that Pilates exercise training should be incorporated in the training programme of Badminton players in addition to the conventional training programme to improve balance, agility, lower limb strength and coordination in aspiring state level badminton players.

ACKNOWLEDGEMENTS

The authors are highly grateful to all the players who participated in the study, to the coach of the badminton academy for supporting in conducting the study and to all others who were directly or indirectly associated with the study.

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FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: Apr 06, 2019

Date of Peer Review: Apr 26, 2019

Date of Acceptance: Jun 04, 2019

Date of Publishing: Jul 01, 2019