Optimizing Performance: Dynamic Neuromuscular control and Accuracy Gains from Tennis-specific Conditioning Program Randomized Control Trail

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Abstract

Background: Tennis, recognized as the second-most popular global sport after soccer it is a high-intensity intermittent sport that demands high levels of technical, tactical, psychological, and physical demands For adolescent tennis players, technical skills and physical demands are critical to securing victories. Tennis necessitates exceptional speed, strength, power, agility and dynamic balance, essential for proficient serving and hitting. The quick change in exercises in plyometric routines enhances players ability to find their center of gravity players become more conscious of bending their knees, ultimately improving their balance, they develop increased power through a variety of muscles working together at one time in an explosive move. We aim to clarify the efficacy and constraints of Tennis Specific exercises method. This comprehensive understanding will serve as a scientific guide for coaches and athletes, and set a baseline for future investigations in enhancing training strategies for tennis players.

Methodology- After preparation of study protocol, Ethical clearance was obtained from IEC (No: PIMS/IEC-02/2022/91. 98 players were screened as per eligibility criteria of the study. Total 92 participants were selected and they were randomized into Group A (n=46) and Group B (n=46) after their consent. Group A received TSCP 3 sessions per week for 12 weeks. Group B continued their regular exercise program.

Result and Data analysis- The Shapiro-Wilk test indicated that the data was not normally distributed hence non-parametric tests was used for data analysis. After 12 weeks the mean between-group difference for the performance of HOP was 3.76 to 4.87 and Tennis Ball shoot Accuracy Score was 6.58 to 10.22 at (95% CI).

Conclusion: Tennis sports-specific training program that incorporates Tennis specific exercises have shown improvement in the level of skill performance-related variables in amateur Tennis players when the program is implemented for 12 week Tennis specific conditioning program(TSCP), when performed into routine workouts, is beneficial for enhancing neuromuscular adaptation and performance of ball shoot accuracy.

Key Words: Physical demands, adolescent tennis, neuromuscular training, functional training, traditional strength training.

Corresponding Author: Dr. Sai Chandrakant Vispute

Mail ID: drsaivisputept@gmail.com

Institution:Shiva Trust College of Physiotherapy, Chatrapati Sambhaji Nagar, Maharashtra, India.

INTRODUCTION

Technical expertise, tactical sense and psychological skill are considered to correlate strongly with tournament success in tennis.[1] However, in the absence of well-developed physical fitness, it is unlikely that these attributes alone will allow a player's potential to be fully realised.[2]

The modern game of tennis has evolved from a primary technical sport with sport-specific technical skills being the predominant factors (e.g., racket and ball handling skills and stroke skills, such as service skill), to a more dynamic and explosive sport characterized by higher stroke and serve velocities and requiring notably higher physical demands.[2]

A sport-specific tennis conditioning programme for competitive tennis players is necessary to maximise performance and reduce the risk of injury. As a framework for developing this programme, both the physiological demands of the sport and the musculoskeletal base of the individual player should be evaluated. The physiological demands of tennis include such aspects as work/rest intervals, primary energy systems, forces related to injuries common to the sport, and sport specific movements.

In an attempt to assess the strengths and weaknesses of a given player, standardized physical testing is commonly used to provide a useful supplement to subjective coaching appraisals [3, 4].

The sports specific training is achieved by using exercises that mimic the actions of the kinetic chains in the specific motor skills in tennis. 6 Particular emphases are placed on the prime movers, without disturbing the motor patterns required for the sports technique. The design of exercise in a micro cycle defines the degree of functionality of the training programme. [5, 6]

The successful performance of a tennis player depends on comprehensive, well-structured periodized, individual specific and long-term training programme develop the complete attributes of tennis players. Long term training generates physiological and metabolic adaptations that impacts sound performance of tennis players. Tennis

players undergo endurance conditioning with scientific support. The design of training should be coined with Frequency, Intensity, Time, and Type (FITT).

We have found previous studies with similar characteristics but are focused on short-term effects: 4 weeks or 6 weeks. Therefore it is still to be established whether chronic improvements can be accomplished with sports-specific training programs over a longer training period.

Our starting point was the fact that the combined training provides broader neuromuscular adaptations which result in greater transfer to a wide variety of performance variables. We hypothesized that the sports-specific training program based on combining sprinting, strength, endurance, jumping, flexibility and agility performance in amateur Tennis players. Therefore, the purpose of the study was to examine the effect of 12 weeks of sports specific training programs on physical and performance-related abilities in amateur Tennis players.

METHOD

Design

A randomized controlled trial was conducted from January 2022 to October 2024 at the Tennis Court of MGM Aurangabad. Potential participants were assessed according to eligibility criteria. Eligible participants who are willing to participate in the study were provided with verbal information about the study and a written information sheet and were required to give informed consent before undergoing baseline assessment and being allocated to a group. Randomization was performed using simple random sampling into two groups: The experimental group and the controlled to conceal the upcoming random allocation, the randomized allocations were concealed in envelopes. The new participant was required to contact the researcher who had no other involvement in the study with the new participant's enrollment details before receiving random allocations whenever they enroll. Before the intervention period, the demographic data and baseline assessment of the study outcome measures were recorded. Participants in the experimental group had undergone 12 weeks of *Tennis Specific Conditioning Program (TSCP)* and those in the control group had undergone 12 weeks of conventional routine exercises. To limit the impact of knowing whether they were in the experimental group or controlled group, participants were advised that the study were compared two exercise regimens and they received no information about the exercise intervention to which they were not allocated. The same researchers reassessed the outcome measures after the completion of 12 weeks of the intervention period. Outcome assessors were blinded to the group to which each participant was allocated.

Participants

92 Tennis players fulfilling the eligibility criteria attended practice sessions regularly. They were aged between 18-24 years, of all genders and qualified PAR-Q. Exclusion criteria were players having any recent injury, any systemic illness and players involved in any other type of personal training methods. No Exclusion was made due to gender or Weight.

Intervention

Experimental group:

Tennis sports-specific training programs were administered which include speed, strength, and endurance training along with core exercises; proprioception and agility drills for 12 weeks (Table. 1). Exercises were progressed after every 4 weeks with alteration in frequency and intensity. The intervention was performed for 60 min/per session and 3 sessions per week for 12 weeks. *Control group*:

Control group intervention continued with the usual training program (Table 2) which include warm-up, Running, Squatting, Strengthening, stretching exercises and cool-down for 12 weeks.

Outcome measures

The Neuromuscular parameters were assessed by Single HOP and Cross over HOP test and performance was assessed with Tennis Ball Shoot Accuracy test. Each parameter was measured using the stopwatch and tape measure and scored and summed for the total score. The best of three trials was considered.

DATA ANALYSIS AND RESULTS

Statistical analysis were performed by using SPSS 23, and as the sample size is less than 2000 so Shapiro-Wilk test used to identify the normality and found that data do not follows normal distribution by ($P < 0.05$). Data set is not normally distributed as all the variables have not indicated p-value greater than 0.05 in the observation. The researcher then used non-parametric test for data analysis purpose in the following sections. The present research work has followed repeated measures so to find out the effect, Repeated Measures of Friedman test is used. $P < 0.05$ considered as statistically significant in the study (CI 95%)

Apart from 2 participants who could not complete the study due to losing their interest in participation, There was no deviation from the study protocol. The registered study questions were assessed, all participants were prescribed their randomly allocated interventions and both registered outcomes were measured at the scheduled time points.

Flow of participants throughout the study:

98 players were screened as per eligibility criteria of the study. Total 92 participants were selected and they were randomized into Group A (n=46) and Group B (n=46) after their consent. (Fig.1) the groups were comparable at baseline as presented. After 12 weeks of assessment 45 participants in the experimental group and 45 participants in the control group were available for assessment and all were measured. Compliance with the prescribed resume was not assessed.

Demographic Data

		Group		Total
		Grp-Exp.	Grp-CTR	
Gender	Female	24	30	54
	Male	21	15	36
Total		45	45	90

Table 3: Characteristics of participants at baseline (n=90)

*Con= control group, Exp = experimental group,

Variable	Group	Mean	SD	z-value	p-value
Age	Exp.	21.87	1.67	0.287	0.774
	Con	21.91	1.86		
Weight	Exp.	58.56	4.87	1.299	0.194
	Con	59.67	4.93		
Height	Exp.	167.80	6.76	NA	NA
	Con	167.80	6.76		

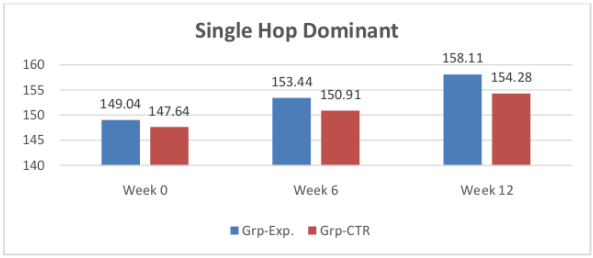
Friedman Repeated Measures Test with Wilcoxon Bonferroni Correction Tests for Single Hop Dominant

Group	Time Frame	Mean	SD	P-value
EXP	Week 0	149.04	23.33	**0.001**
	Week 6	153.44	23.27	
	Week 12	158.11	23.16	
CTR	Week 0	147.64	23.39	0.001
	Week 6	150.91	23.33	
	Week 12	154.28	23.23	

There was a statistically significant difference in outcome for Single Hop Dom as Chi-Square is significant with p-value < 0.05

Repeated measure post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.005$

Overall experimental group is better based on higher Chi-Square value and Z- value for within group and between groups analysis respectively

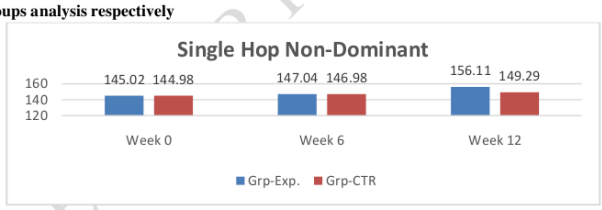


Friedman Repeated Measures Test with Wilcoxon Bonferroni Correction Tests for Single Hop Non-Dominant

Group	Time Frame	Mean	SD	P-value
EXP	Week 0	145.02	23.38	0.001
	Week 6	147.04	23.70	
	Week 12	156.11	23.52	
CTR	Week 0	144.98	23.63	**0.001**
	Week 6	146.98	23.58	
	Week 12	149.29	23.48	

Statistically significant difference in Single Hop Non-Dominant as Chi-Square is significant with p-value < 0.05 ,Repeated measure post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.005$

Overall Experimental group is better based on higher Chi-Square value and Z- value for within group and between groups analysis respectively

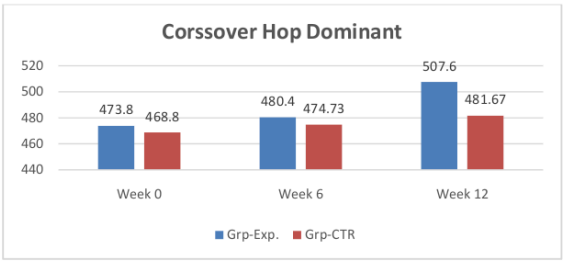


Friedman Repeated Measures Test with Wilcoxon Bonferroni Correction Tests for Crossover Hop Dominant

Group	Time Frame	Mean	SD	P-value
EXP	Week 0	473.80	50.66	**0.001**
	Week 6	480.40	50.64	
	Week 12	507.60	50.25	
CTR	Week 0	468.80	54.82	0.001
	Week 6	474.73	55.41	
	Week 12	481.67	55.44	

There were significant differences between the time frames as observed from the above table with p-value being less than 0.05 (0.001 < 0.05). Overall all the pairs have revealed statistical differences due to medical treatment over the extended period of time from week 0 to week 12 time period

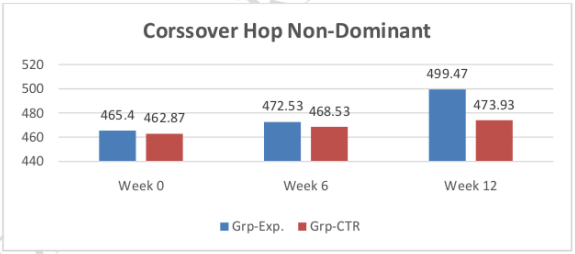
Overall experimental group is better based on higher Chi-Square value and Z- value for within group and between groups analysis respectively



Friedman Repeated Measures Test with Wilcoxon Bonferroni Correction Tests for Crossover Hop Non-Dominant

Group	Time Frame	Mean	SD	P-value
EXP	Week 0	465.40	48.94	**0.001**
	Week 6	472.53	49.36	
	Week 12	499.47	49.29	
CTR	Week 0	462.87	55.37	0.001
	Week 6	468.53	55.94	
	Week 12	473.93	55.68	

Overall experimental group is better based on higher Chi-Square value and Z- value for within group and between groups analysis respectively



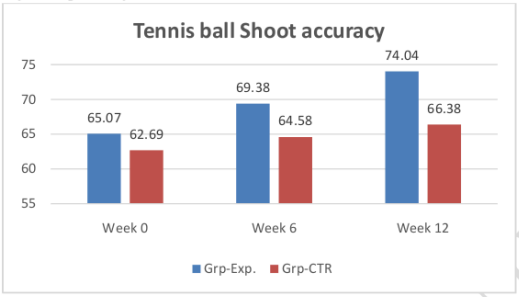
Friedman Repeated Measures Test with Wilcoxon Bonferroni Correction Tests for Tennis ball Shoot accuracy

Group	Time Frame	Mean	SD	P-value
EXP	Week 0	65.07	7.35	**0.001**
	Week 6	69.38	7.67	
	Week 12	74.04	7.51	
CTR	Week 0	62.69	7.07	0.001
	Week 6	64.58	7.22	
	Week 12	66.38	7.24	

There was a statistically significant difference in medical treatment outcome for Tennis ball Shoot accuracy as Chi-Square is significant with p-value < 0.05

Repeated measure post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.005$

Overall experimental group is better based on higher Chi-Square value and Z- value for within group and between groups analysis respectively



DISCUSSION

This study estimated that a Tennis Specific Conditioning Program that combines various training methods like strength, speed, agility, balance, etc was more beneficial than conventional training for several outcomes including Selective Neuromuscular Adaptations and Performance outcomes in amateur Tennis players.

The neuromuscular training component included strategies to enhance dynamic balance and agility during both jump training and sport-specific drills. The players were taught to control the upper body, trunk, and lower body position; lower the center of gravity by increasing hip and knee flexion during running, jumping, landing; and land with smaller ground reaction forces. These strategies were also encouraged during the agility and speed drills that involved straight running, lateral movements, and backwards jogging with and without hitting a ball. The plyometric component was used to not only train for power and explosive movements but also to enhance the players' ability to decelerate quickly in a safe manner [7]. The ability to efficiently decelerate in tennis is just as important as the ability to accelerate, because the player must be able to stop and change direction in the time period required making optimal ball contact and being in position to continue the rally.

The ability to control the body during both acceleration and deceleration translates into superior dynamic balance and ultimately, performance. Malliou et al. [8] recommended that balance training be incorporated into tennis training programs after noting a fatigue-induced decline in balance performance in 36 elite tournament players. In addition, it is believed that many lower extremity injuries occur because of poor balance and deceleration techniques or an overabundance of acceleration training that is not balanced with deceleration training [7].

Salonikidis and Zafeiridis [9] assessed the effects of 3 training programs on 64 novice tennis players aged 21.1 ± 1.3 years on speed, reaction time, tennis-specific movements, and power of the lower limbs. The programs comprised either plyometric training (6 plyometric exercises), tennis-specific drills training (6 running drills), or a combination of both and were conducted 3 times a week for 9 weeks. The authors reported that the combined training program appeared to be the most advantageous because it resulted in a significant improvement in most of the tests conducted including reaction time, 4-m side steps, 4-m and 12-m sprint runs, drop jump, and lower extremity maximum isometric force.

They videotaped the single-leg hop tests to show the athlete and parents the player's body position on landing to determine if they had adequate control of the core, upper extremity, and lower extremity. They found subjectively that only approximately one-third of the players were able to maintain an adequate body position on landing before training . After training, marked subjective improvements were noted in the neuromuscular control on landing .The improved technique translated into superior confidence and significant increases in the distance hopped in the triple crossover hop. They believe this test provides a measure of dynamic balance in addition to limb symmetry, more so than the single hop for distance task.

TENNIS BALL SHOOT ACCURACY

Current study estimated that a Tennis Specific Conditioning Program that combines various training methods was more beneficial than conventional training for improvement in tennis ball shoot accuracy performance in amateur Tennis players.

Previous literature suggest that Resistance Training causes a higher impairment in stroke performance and, as a consequence, it is important to be more careful when applying Resistance Training method, especially close to the competition. The poor accuracy reliability in serve could be due to the greater technical difficulty of serve than groundstrokes. Also, the literature states it was probably due to the subjects that were asked to hit the ball at maximum velocity, causing more variability in the accuracy and consequently decreasing the reliability. This fact has been observed in tennis [10] and dart throwing [11], though there is some controversy because it has also been observed a positive correlation between velocity and accuracy in tennis [12].

On the basis of previous investigations [13, 14], we hypothesized that functional training, when incorporated into standard tennis training, could enhance skill performance more than standard training. The data, however, seem to suggest otherwise. Over an average length of time, standard training—which is based on a coach's several decades of expertise in coaching tennis sport—is beneficial for promoting the performance of young male tennis players. Consequently, a tennis coach may select any approach to elicit tennis—skill performance, and the outcomes should be equivalent within the time span investigated in this study, even if functional training also showed its efficacy in our group. Moreover, these skill—performance modifications are expected to develop within six to 12 weeks. However, the conclusion that functional training can significantly improve athletes' skill performance has been confirmed in other types of athletes. Liu et al. (2023) revealed that 3 sessions per week of functional training for 12 weeks improved the accuracy and depth test scores among national—level tennis players [15]. Chen (2023) reported that 8 weeks of functional training with a frequency of 3 sessions per week led to improvements in depth and hitting accuracy test scores among national—level badminton players [11]. Another author reported that 8 weeks of functional training among club Tennis players could improve athletes accuracy in shooting skills from outside the three-point arc [16]

In addition, Lee et al. (2023) revealed that 3 sessions per week of functional training for 6 weeks improved the batting speed of collegiate baseball players [12]. These findings demonstrate that functional training regimens might significantly improve athletes' skill performance. One interpretation of the findings of this study is that functional training can enhance an athlete's capacity to regulate their body posture and technical movements, increase the effectiveness of power transmission, and increase their ability to precisely control their motor nerve in relation to the racket [13, 17]. Moreover, an additional plausible rationale could be the functional training specificity principle, which advocates for training in a manner that simulates the intended action to enhance the target movement itself, rather than targeting individual muscle groups [18, 19, 20]. However, workouts that improve muscle strength and durability are used in conventional training. Owing to the unidirectional nature of these workouts, which mainly use the sagittal plane, only the necessary muscles quickly become stronger under high stress. Additionally, functional training is superior to regular training for tennis player performance enhancement since it exercises many axes simultaneously, employing multiple muscle groups and joints along with mimicking sports specific exercises.

Also, a significant improvement in movement quality was observed after the functional training intervention. This finding was not unexpected because functional training attempts to develop muscles in corresponding multiplanar movements and intergrate multiple joints, dynamic tasks and constant changes on the basis of support to improve the athlete's postural control, reduce energy consumption during movement completion, and improve the power transmission efficiency chain at the end of the movement [20, 21]

Literature has also shown that if muscles being used are not exercised in accordance with the principles of functional training, the quality of movement may deteriorate even though individual motor skills may improve. Traditional resistance training is not always multiarticular or multiplanar and therefore may overlook the importance of an athlete's functional limitations and their ability to perform coordinated functional movements accurately[22]. Previous research has validated these findings and demonstrated that functional training can significantly enhance the quality of mobility for various athlete populations [23, 24]. Campa et al. (2018) reported that 20 weeks of a functional training program significantly improved the movement quality of elite male soccer players [25]. Riela et al. (2019) reported that 8 weeks of functional training, three times a week, significantly improved the movement quality of male professional soccer players Suzuki et al. (2022) reported that 12 weeks (four sessions per week) of functional training greatly improved the movement quality of high school baseball players. Tennis involves multiple muscled groups joints are exercised multiple axes simultaneously, and their explosive movement patterns place a high demand on athletes' movement quality. However, better movement quality can both enhance athletes; performance and successfully prevent sports injuries. Therefore, it is recommended that athletes and coaches exercise according to the functional training principles.

The training program designed in this study is a calculated approach which involves specific exercise plans, intended to rise the levels of fitness in amateur tennis players. The result of the present study supports the hypothesis that incorporating tennis specific conditioning program into regular training of amateur tennis players will induce more significant improvement in selective neuromuscular adaptations and performance variables.

CONCLUSION

This study contributes to growing body of literature on effects of sports specific conditioning on improving the Neuromuscular adaptations and skill performance in amateur Athletes.

The findings of the present research indicate that tennis specific conditioning programs can improve Neuromuscular adaptations along with tennis ball shoot accuracy among Amateur tennis players more than standard training programs.

Therefore, it could be suggested that Tennis Specific Conditioning Program can be useful to train to maximize the skills and tennis performance in amateur tennis players.

Table- 1: Content and progression of the experimental group intervention

Warm-up(5-7min)	General mobilization, Single hop jumps, High Knees, Buttock Kicks, Tennis, Stretching		
LEVEL - I			
Exercise category	**Exercises**	**Level I Week 1-4**	
		Reps.	**Sets**
Running Exercises	Straight running 100m	2	1
	Alternate leg bounds	2	1
	Side Stepping Running including side stepping	2	1
	Running Back and Front	2	1
	Suicide Run	2	1
Agility Drills	Agility - Cone Calls	8-10	2
	Ladder Drill –Split steps	8-10	2
Strength, Endurance	Push ups	8-10	2
	Squats	8-10	2
	Plank	3	2
	Shoulder Tap Plank	3	2
	Side Plank.	3	2
Proprioception (Balance Drills)	Drop feed ball and hold	10sec hold	3
Plyometrics & Motor Control (Involving Trunk Twister)	Skipping	100	2
	HOP Jumping	8-10	2
	Crook lying with pelvic & trunk rotations:	8-10	2
Speed Drills	Speed	8	2
LEVEL - II			
Agility Drills	Acceleration / Deceleration Drill	6-8	2–3
	Ladder Drill – 2 in forward	3	1

Strength, Endurance	Push up	15-20	2
	Squats on toes	10-12	
	Plank	15-20 sec hold x 5 reps	
	Shoulder Tap Plank	10-12 times each. 5 reps	
	Side Plank	Hold for 20 sec. 5 reps	
Proprioception (Balance Drills)	Balancing with soft tennis ball	8 -10/sessions	2
Plyometrics & Motor Control (Involving Trunk Twister)	Mountain climber exercise	10 to 12 reps	2
	Lateral Jumping	2 reps for 30 seconds	
	Whole body coordination while trunk twisting	8-10/session	
Speed Drills	Speed	6 -8/session	2
LEVEL III			
Agility Drills	*M Drill*	5 times	2–3
	Ladder Drill – Lateral in and out	2 /session	1
Strength, Endurance	Push up	25-30 reps	2
	One leg Squats	8 to 10 reps	
	Plank	30 sec hold x 5 reps	
	Shoulder Tap Plank	10 -12 times each. 5 reps	
	Side Plank	Hold for 30 sec. 5 reps	
Proprioception (Balance Drills)	Ball Hits balancing on BOSU Ball	10 -15 sec hold 8 to 10 hits / session	2
Plyometric & Motor Control (Involving Trunk Twister)	Single leg over 10 cones	2 reps	2
	One leg box jump	8 to 10 times	
	Trunk Twist	8-10 / session	
Speed Drills	Speed	6 -8/session	2
Cool down (5-7 min)	Spot Jogging, Stretching of major Group of muscles		

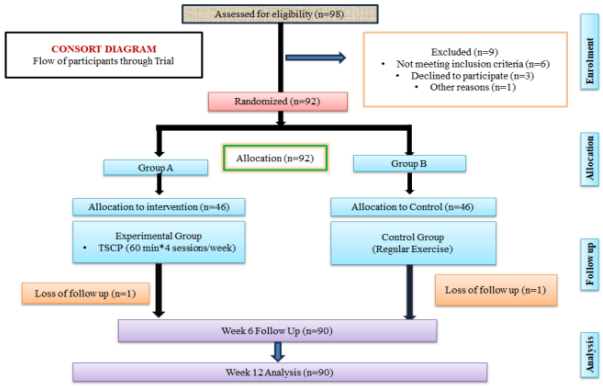
*Three sessions per week were prescribed, Min=Minutes, Reps=Repetitions

Table- 2: Content and progression of the control group intervention

Exercise Category	Exercise	Volume	
Warm Up	ROM, Jumping Jacks, Skipping , Jogging 5 to 7 mins (1- 12 weeks)		
		Reps	Sets
Strength Endurance Training	Pull Ups	10	3
	Squats	10	2
Aerobic group exercise Session	Running 200 mts	2	1
	Curl Ups	10	3
	Free Hits	10	3
Cool Down	Stretching of Major group of muscles, gentle walk for 5 minutes.(1- 12 weeks)		

*Three sessions per week were prescribed, Min=Minutes, Reps=Repetitions

Figure 2. Design and flow of participants through the trail



Footnotes: IBM SPSS23 Software Windows V.28.0.10 version (Statistical package for social science), SPSS Ethics approval: The Institutional Ethics Committee(s) approved this study. (PIMS/IEC-DR/2022/91). All participants gave written informed consent before data collection began.

Competing interests: NIL

Source(s) of support: NIL

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Correspondenc Dr.Sai Chandrakant Vispute, Department of Musculoskeletal Physiotherapy, Shiva trust College of Physiotherapy, Chatrapati Sambhaji Nagar, Maharashtra India.

Email: drsaivisputept@gmail.com

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