

Testosterone and Functional Speed Adaptation to Combined Lower limb Neuromuscular and Motor Coordination Training in Collegiate Badminton players: A Randomized Controlled Trial

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Abstract

Background: Hormone influence the body function which causes biochemical and metabolic changes. Physical function are to be considered as strong influencer for the endocrinal variability mainly the testosterone and cortisol.

Aim: The study was aimed to examine the impact of combined lower limb neuromuscular training and motor coordination training on the level of testosterone among the male and female collegiate badminton players.

Methods and Material - Randomized controlled trail was performed with inclusion of Collegiate Badminton players (16-25 years) of both genders which were recruited from the university and colleges. Ethical consent and CTRI was done before starting the study.

Statistical analysis: The analysis was done using software SPSS 24 version 2.0. Pearson's test, Independent T test were performed. P values were taken significant <0.05.

Results: The findings were signifying an enhancement of training regime in level of testosterone in experimental group whereas control group was also detrimental enhancement but the changes were minimal and no substantial. Similarly, Speed was demonstrating noticeable improvement in values among the participants of experimental group whereas the control group was not showing any meaningful progress. Additionally, the progress was more noticeable among males than females.

Conclusion: The exercise programs are effective and strong stimulators for the enhancement in values of testosterone as free marker of performance. As some sports also shows such findings and remained it as a marker of performance among the athletes.

Keywords: Hormone, Testosterone, Neuromuscular, Motor, Coordination

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Introduction

Hormones include various important factors such as testosterone which is a powerful stimulatory agent for protein synthesis in relation to muscle metabolism (Griggs et al., 1989). Testosterone acts as a vital androgenic anabolic substance and a strong stimulator for different training and adaptation in human. The variability of training and competition has shown changes in level of testosterone due to various biomarkers such as - anxiety, mental stress and physical potency as well¹. Growth and maturation of male's prostate is influenced by testosterone and distribution of hair growth, muscle mass and even energy level of human impacted by levels of testosterone in body¹⁷. Physical activity, including the exercise works as a potent agent for hormonal variation conferring to the former available texts. HIIT (High intensity intermittent training) including strength, resistance and other incorporating physical activity are to be an igniting mediator for changes in testosterone⁴. Despite these

studies, the tapering shows a deterioration response to training in association to detraining which also indicates a reduced value of testosterone⁷.

According to Hakkinen et al, 2000, Tsolakis et al., 2004, it was demonstrated that neuromuscular adaptations occur which is mediated by the acute level of testosterone raising after the completion of training. This process shows changes at microcellular levels due to cellular responses to the exercise/training¹⁵. Peak power of muscle, a critical determinant for performance of an athlete declines with age which shows an association with deterioration in serum testosterone¹¹. An athlete's ability to produce some action and execute the peak power are influenced by their psychological, physical and tactical capabilities. The physical capability is one of most influenced determining factor for a player's performance. Various training were depicting the impact on the hormonal part even by varying the situation by simulation of environment, sport and physical situation.

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Neuromuscular training is a type of strength and fitness training integrating fundamental and sport specific movements enhancing different physical fitness outcomes e.g. agility, power, balance and speed¹. On the other side, the lower limb motor coordination training also shows impact on various motor markers such as balance (static and dynamic), speed and agility. So this study needs to evaluate the impact of combined neuromuscular training and lower limb motor coordination training among the collegiate badminton players on biochemical level of testosterone by using a well-structured exercise program on day's basis in a week with resting intervals.

Material and Methods

Ethical approval (including CTRI) - An Ethical Committee approval was taken from Teerthanker Mahaveer University Moradabad, with Registration Number (TMDCRC/IEC/PHD/24-25/PHYSIOTHERAPY/01) in Year 2025. Clinical Trial Registration (CTRI/2025/07/091355) was done before starting the study and ethical certification. The inclusion of participants was considered according to the ethical standards of institution.

A Randomized Controlled Experimental Trial was taken as a reference for study.

Participants - The collegiate badminton players were recruited on the basis of inclusion and exclusion criteria by restricting to age group (16-25 years) with both genders (male and female), with no history of endocrinal disease. Age groups of (<25 and >16 years) were excluded with history of endocrinal disorder (if any) and those who were diagnosed with serious musculoskeletal injury were also kept out from the study.

Apparatus - Cones, Sports Ladder Stopwatch, disposable Needle (3 ml) were used to collect the samples before (baseline values) and after the study (post training value).

Procedure - A Randomized Controlled Trial was taken as a reference study design for study. A consent form was developed with details of study and its risks and benefits in both English and Hindi language and the data was extracted in the data collection sheet with demographic details. Sample was calculated by G power software

version 2.0 on the basis of effect size 0.5663851 and the power 0.80. Total of 36 participants (18 males and 18 females) were randomly (Lottery method) allocated to both groups (Experimental and Control) with equal population of both genders (male and female).

Blood sample for testosterone by Medical Lab Technician expert from the anterior venous area of forearm was obtained 1 day before starting the training. The sample was reserved in vacutainer for serum testosterone analysis to keep the quality control and further on processed in medical laboratory for ELISA (Enzyme linked immunosorbent assay $r = 0.90$ and $v = 90\%$) test to record the pre-recordings (Baseline value). The outcome measures values (30m sprint test) by the principal investigator were recorded before starting the training (Day 1) from the population of both the groups (Experimental and Control). The participants were instructed to perform the warm up exercises in the experimental group before starting the training and the training regime was introduced and performed with the specific days of week. Lower limb Neuromuscular training was given thrice a week (Monday, Wednesday and Friday) with 2 batteries of exercises as listed (Table 1) at an interval of 30 minutes in between with total of 6 and 7 exercises in both batteries with different frequency and durations, whereas the lower limb motor coordination training was incorporated for 3 times a week (Tuesday, Thursday and Saturday) on alternate days including 3 reps of each exercise with 1 set and total of 13 exercises with a rest of 1 day in week (Sunday). The exercises were administered among experimental group without any progression as the exercises detailed in table 1 and 2 with respective repetitions and set. This training was given for total of 8 weeks duration, with no training regime to control group continuing with their daily activities. The control group was asked to continue with their daily activities for next 8 weeks and also instructed for any endocrinal disorder if found during this period with consultation of endocrinal expert. The blood sample was taken after completion of 8 weeks (Day 57) 30 minutes after the training for experimental group. The physical outcome measure (30m Sprint test) was performed in day 57 to record the data for both experimental and control groups for each participant.

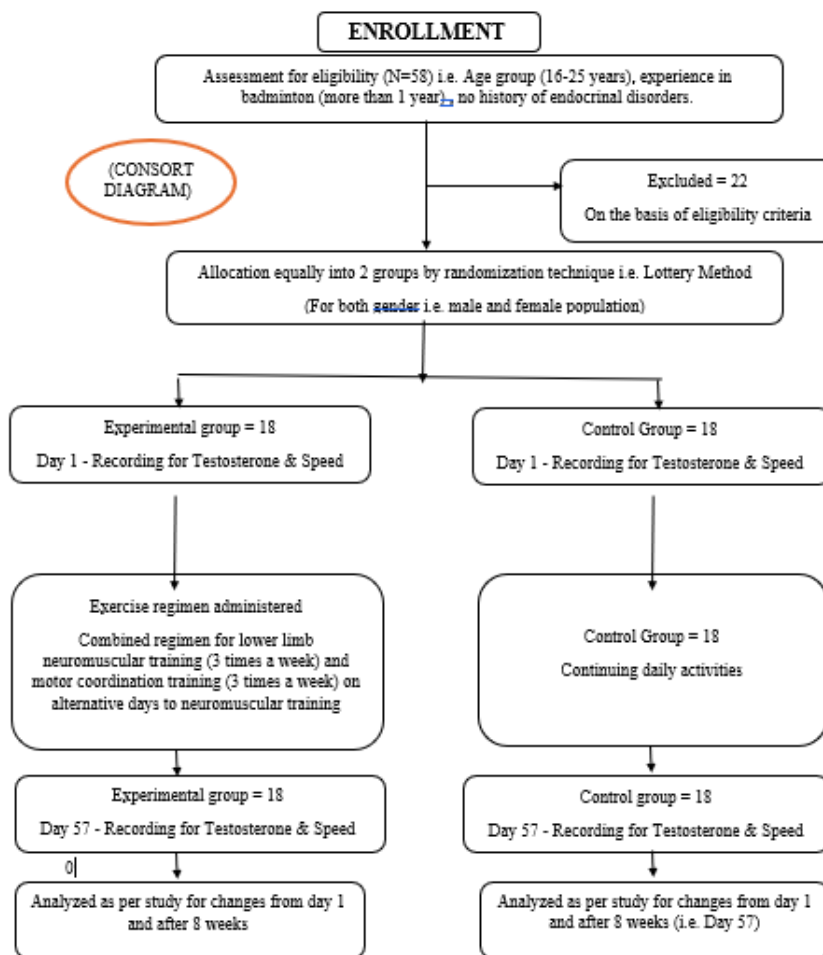


Figure 1 - Consort diagram for the study

Exercise Regimes –

Table 1: Neuromuscular training (thrice a week only) for 8 weeks

Sr No.	Warm Up	1st Battery of Exercises	30 minutes rest	2nd Battery of Exercises
1	Heel Walking – 10m	Isometric squats – 15 sec hold-6 squat jumps		Isometric forward lunge – Hold 15 secs for each Leg (balance disc under front foot)
2	Toe Walking – 10m	Plank – 30 sec hold		Straight arm plank on Swiss ball 15 secs
3	Forward lunge with trunk rotation – 12 reps	Isometric forward lunge – hold 15 secs – 6 reverse lunge for each leg		Isometric squat on reversed Ball- 6 squats Dynaso Bosu balance trainer - 30 sec for each leg
4	Inchworm push up – 6 reps	Isometric push up – 10 sec hold – 6 push up		One leg deadlift using kettlebell in hand - 5 repetitions
5	Rollover into V-Sits-6 reps	Isometric single leg hip bridge – 15 sec hold for each leg		Glute bridge with alternating front kicks (legs on reversed Ball- Dynaso Bosu balance trainer (10 repetitions)
6	Spiderman lunge with vertical rotation – 8 reps			Side to Side jumps (5 on each side)
7	Bent knee iron cross – 12 reps			
8	Squat to stand – 8 reps			

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9	Straight leg raise – 8 reps for each leg			
10	Groiners – 10 reps			
11	Leg swing front to back & side to side – 10 reps each leg			
12	Jumping jacks – 10 reps			

Cahn, U. (2019). Effects of Neuromuscular Training on Motoric and Selected Basketball Skills in Pre-pubescent Basketball Players. Universal Journal of Educational Research, 16-23.

Regime 2

Lower limb motor coordination training strategy

The players receive a booklet with ladder drill exercises program chart. It includes total 6 weeks of training. 8 weeks (3 times/ week on alternative days).

Sr No.	Exercises	Set/Reps
1	Explosive pushes	1x3
2	In and Out	1x3
3	In, In, Out, out	1x3
4	Side pushes	1x3
5	In, in, Out, out - Sideways	1x3
6	Step running	1x3
7	One leg jump	1x3
8	Two foot forward	1x3
9	Two foot sideways	1x3
10	Icky shuffle	1x3
11	Backward icky shuffle	1x3
12	Foot exchange	1x3
13	Two footed hops	1x3

Abelsattar, M., & Mohammad, K. (2018). Effects of an Eight Week Motor Coordination Program Using Elastic Bands on motor Speed, Agility, and Power for 15-year-old Soccer Juniors. International Journal of Sports Science and Arts, 3, 110-133.

Outcome measures - Speed and biochemical level of testosterone (Blood sample for serum testosterone) were taken as outcome measures. Variables were taken as 30 meter sprint test and blood sample of testosterone (serum testosterone).

Statistics - The analysis was done from using SPSS 24 Version 2.0 by applying the Pearson's test, Independent T test, calculating p values and Normality Distribution for Demographic Variables. Mean differences between the variables and p values were taken significant <0.05 and >0.01.

Results - Baseline characteristics representing Table 3, females 22.38 + 1.99 years in control, and 20.67 + 2.23 years in experimental group whereas males with mean age 20.20+2.48 years in control and 21.0+2.39 years in experimental group. Mean BMI was in range of 24.71 + 2.66 and 24.56 + 1.59 for males and for female, 20.85 + 1.99 and 21.14 + 2.30. Weight, Height were closely matching among groups indicating the homogeneity at baseline. In Table 4, the data depicting the changes in different groups for speed and testosterone among male and female population of sample and demonstrating the marked changes in level of testosterone among males (521.47+5.82 to 645.91+7.91) with more of values than females (36.79+5.82 to 43.96+7.91) in experimental group with notorious changes in females.

Table 3: Normality data distribution in both groups and gender

Demographic Details		Control Group	Experimental Group
Age (in years)	Male	20.20+2.48	21.0 +2.39

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	Female	22.38 + 1.99	20.67 + 2.23
BMI (kg/m ²)	Male	24.71 + 2.66	24.56 + 1.59
	Female	20.85 + 1.99	21.14 + 2.30
Weight (In Kg)	Male	75.93 + 12.05	76.83 + 8.29
	Female	59.35 + 4.78	58.85 + 3.98
Height (In Cm)	Male	177.70 + 9.33	176.44 + 6.5
	Female	169.13 + 3.22	169 + 2.73

Table 4: Inter and Intra group comparison of testosterone and speed (male vs female & control vs experimental)

Variable	Group	Gender	Pre-test (Mean ± SD)	Post- test (Mean ± SD)	Δ Change (Post- Pre) Mean ± SD	Within- group (t, p)	Between- group (Exp vs Ctrl) (t, p)	Between- gender (Male vs Female) (t, p)
Testosterone (ng/dL)	Experimental	Male	521.47 ± 5.82	645.91 ± 7.91	+114.51 ± 38.2	-3.007, 0.001*	4.62, 0.000*	7.84, 0.000*
		Female	36.79 ± 5.82	43.96 ± 7.91	+10.63 ± 6.4	-2.421, 0.000*	3.24, 0.003*	7.84, 0.000*
	Control	Male	541.88 ± 6.40	557.08 ± 4.67	+11.94 ± 32.1	-7.149, 0.000*	—	1.14, 0.262 (NS)
		Female	35.44 ± 3.71	37.18 ± 4.25	+1.28 ± 5.9	-4.340, 0.002*	—	1.14, 0.262 (NS)
Sprint Time (seconds)	Experimental	Male	3.90 ± 0.21	3.71 ± 0.25	-0.33 ± 0.15	0.248, 0.001*	3.98, 0.001*	2.96, 0.006*
		Female	5.78 ± 0.70	5.35 ± 0.54	-0.17 ± 0.08	0.039, 0.000*	2.84, 0.008*	2.96, 0.006*
	Control	Male	4.12 ± 0.66	4.12 ± 0.71	-0.02 ± 0.09	2.609, 0.031*	—	0.27, 0.789 (NS)
		Female	5.42 ± 0.15	5.41 ± 0.16	-0.03 ± 0.11	7.599, 0.000*	—	0.27, 0.789 (NS)

*- Significant, NS-Non Significant SD - STANDARAD DEVIATION, Δ- Change (pre and post)

However, the control group was not notorious in this context (541.88+6.4 to 557.08+4.67) because of substantial enhancement in values (testosterone) but the speed values were varying among both of population (male and females) in experimental group (3.90+0.21 to 3.71+0.25) and (5.78+0.70 to 5.35+0.54). Whereas in table 4, it was described that the

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changes in testosterone were significant among males and females both in experimental group but the sprint values were not showing similar changes because of gender specificity and variable values (males 0.003 and females 0.008). Table 4 and figure 2 and figure 3 representing the data on the basis of gender which was further demonstrating the impact of training on testosterone values and sprint values among males with significant enhancement. The heat map also proves the strong positive correlation in changes of testosterone among collegiate badminton players. The figure 4 illustrates the heat map showing significance and correlation of testosterone and sprint capability demonstrating the relationship between the physical fitness (sprint as a marker) and level of testosterone.

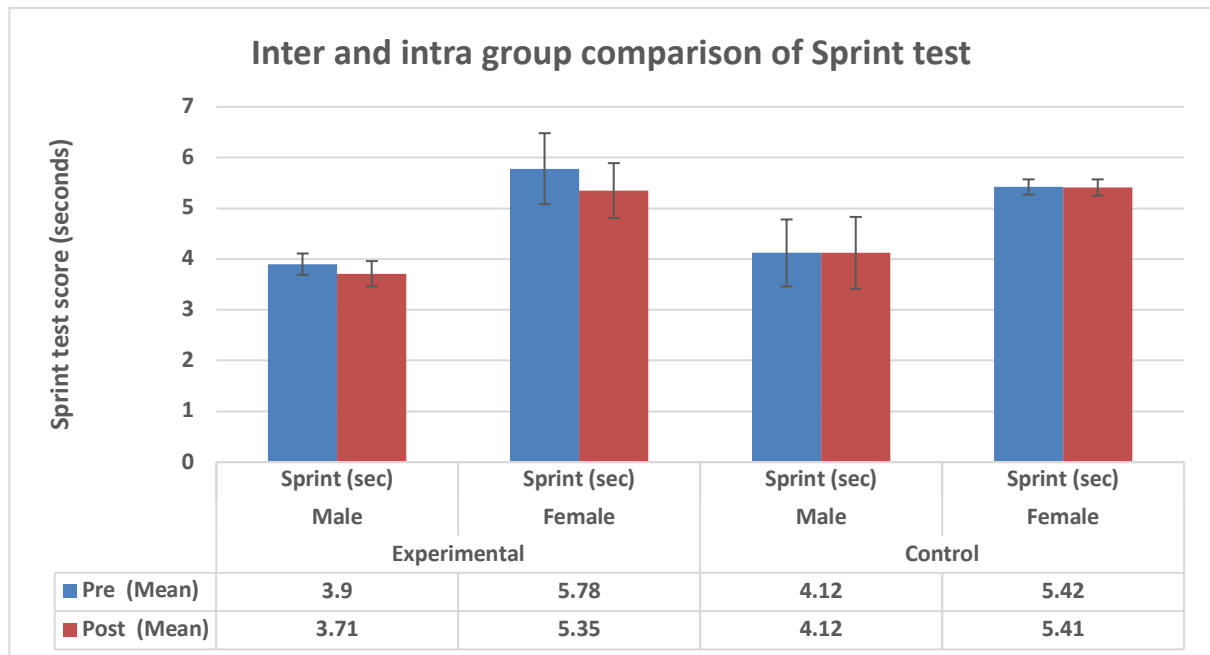


Figure 2: Inter and Intra Group comparison of Sprint test for Participants

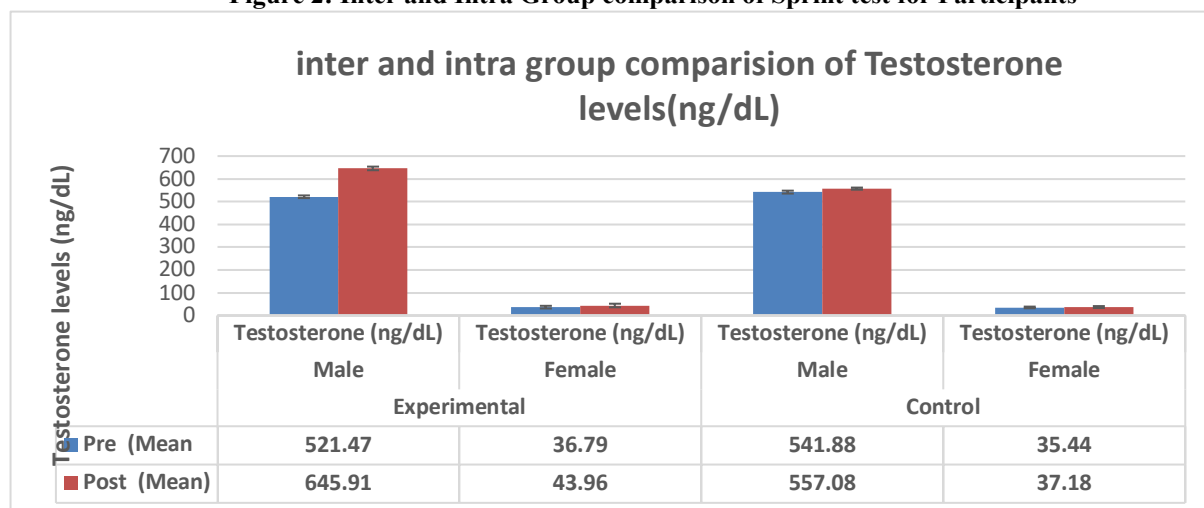


Figure 3: Inter and Intra group comparison of testosterone levels (ng/dl)

Correlation Heat Map -

Variables	Correlation	Age (years)	BMIKgm2	Pre Testosterone Level (ng/Dl)	Post Testosterone Level (ng/Dl)	30M Sprint Test PRE (In second)	30M Sprint Test POST (In Seconds)
Pre TEST Level (ng/Dl)	Pearson's r	-0.105	0.612***				

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Post TEST Level (ng/Dl)	Pearson's r	-0.078	0.591***	0.981***			
30M Sprint Test PRE (In seconds)	Pearson's r	0.078	-0.652***	-0.846***	-0.834***		
30 M Sprint Test POST (In Seconds)	Pearson's r	0.146	-0.655***	-0.837***	-0.837***	0.949***	
Note. * $p < .05$, ** $p < .01$, *** $p < .001$							
Strong positive correlation			Strong negative correlation				
Weak positive correlation			Weak negative correlation				

Figure 4: Heat map on the basis of correlation for different outcome measures (testosterone and sprint test in before and after the exercise regime)

Discussion

The findings demonstrated that the structured exercise program consisting of both the motor coordination and neuromuscular training enhanced the testosterone levels and the performance of sprint among collegiate badminton athletes. Females were showing lesser improvement than males in both outcome measures (speed and testosterone). The strong positive correlation between testosterone and sprint performance highlights hormonal contribution to the performance. A fabled image of exercise causing changes in testosterone emerges when the integration of all studies was done by assessing their quality and methodological analysis. As illustrated by Midttun et al. (2024), Cadore and Krul (2012), and Jensen et al. (1991) shows a drastic changes in level of testosterone and cortisol which were affected by resistance training elevating levels of testosterone considered for instance a potent stimuli as resistance exercise. Some studies performed among the athletes by Venckuas et al. (2019) and Song et al. (2023) showing potent hormonal adaptation following these trainings.

Conversely, these studies were having some deficiencies due to the leftover data and their individual method used in study. Across these all, the Tapering and Aerobic exercise shows a potent stimuli to change the responses to testosterone and its biochemical values at free and total testosterone in different samples (salivary, blood sample) at various intensity of training marking adaptation among the young and elder population. The tapering was also declining the testosterone levels which were contradictory but can be depicted as variable intensity of exercise causing indirect impact on hormonal adaptation.

Conclusion

Significant enhancement can be observed in badminton collegiate players with lower limb neuromuscular and motor coordination training. Emphasizing the male population mainly, the adaptation shows a sex dependent part due to androgenic responsiveness and muscle recruitment patterns in males.

Limitation

The study's finding are to be interpreted with limited sample population size and limited to a specific sport badminton from a particular region which can further restrict the generalizability of findings, can vitiate to other sport or broader population. Additionally, the type of training, lifestyle and mainly the population to direct sport people who are playing professionally with athletic discipline.

Ethical approval

An Ethical Committee approval was taken from Teerthanker Mahaveer University Moradabad, with Registration Number (TMDCRC/IEC/PHD/24-25/PHYSIOTHERAPY/01) in Year 2025.

Authors' contributions

The corresponding author Himanshu was collected the data and managed for database. The conceptualization and final editing was done by Dr Amit Saraf and Dr Pooja Anand contributed for results and discussion part.

Data availability

Data could be availed on request from the corresponding author.

Clinical trial registration

Clinical Trial Registration (CTRI/2025/07/091355) was done before starting the study and ethical certification

Consent to participate

The written consent form copy duly signed by participants in English and Hindi both were obtained.

Conflict of interest - It is hereby to declare that there was not any conflict of interest among the authors.

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