



COMPARISON OF SWISS BALL EXERCISE VERSUS PLYOMETRIC TRAINING FOR IMPROVING DYNAMIC BALANCE IN COLLEGE GOING BADMINTON PLAYERS

*¹Koya Devendar Reddy, ²Pilladi Chaturvedi, ³Dr. Patchava Apparao and ⁴Dr. Ch. Ganapathi Swamy

India.



*Corresponding Author: Koya Devendar Reddy

India.

Article Received on 21/02/2024

Article Revised on 11/03/2024

Article Accepted on 01/04/2024

ABSTRACT

Background and objective: Performing well and avoiding injuries are the goals of dynamic balance for badminton players. Performance of the players is greatly influenced by the dynamic balance. In order to control their center of gravity and respond to a variety of scenarios that could jeopardize their equilibrium, such as twisting movements during jump smashes and offensive and defensive attacks, badminton players must be well-balanced. To compare the effectiveness of Swiss ball exercise versus plyometric training for improving dynamic balance in college going badminton players. **Methods:** Randomized control trial. In this study, 60 subjects were recruited out of 100 were screened between the age group of above 18 years and were randomly allocated into two groups. Each group containing 30 subjects. Group-A received Swiss ball exercise and Group-B received plyometric training. Participants received 3 session per week for 6 weeks. The outcome measures of this interventions were measured in term of star excursion balance test for dynamic balance. **Results:** Independent t-test was used to compare the mean significance difference between continuous variables. Paired t-test was used to assess the statistical difference between pre-test and post-test scores p value of (0.0001). Statistical analysis of the data revealed that within the group comparison, both groups showed significant improvement in all parameters. Whereas, in between the group's comparison Swiss ball exercise group A showed better improvement. **Conclusion:** After six weeks of training both the groups showed significant improvement in dynamic balance in college going badminton players. However the Group-A who received Swiss ball exercise has showed more improvement when compared to plyometric training.

KEYWORDS: Swiss ball exercise, plyometric training, Star Excursion Balance Test, Dynamic Balance, College going Badminton players.

INTRODUCTION

Around 150 million people worldwide are estimated to play badminton, and more than 2000 players compete in international events, according to the badminton global federation.^[1] One of the quickest racket sports with brief breaks and tremendous intensity is badminton.^[2,3] In a very short period of time, the badminton players must make decisions based on predictions of the opponent's movement and the trajectory of the badminton.^[4]

Although badminton has grown in popularity since it was added as an official sport to the 1992 Olympic Games in Barcelona, there is still a dearth of study on performance capacity (the highest level of performance that players are capable of reaching, which should serve as a benchmark for coaches of elite player,^[5] The coordination of motions with muscular activity, vestibular somatosensory, visual, and other complex interactions all revolve upon maintaining balance.^[6]

One of the most played racquet sports worldwide is badminton, which is a non-contact activity. It's a sport that draws a lot of athletes, both competitive and recreational, and it works well for all ages and skill levels. In an 80 m² court, badminton is a game of quick, repetitive movements that require high speed and energy. Players must have quick reflexes to accomplish changes of direction, hops, forward lunges, rapid arm motions, and a wide range of dynamic postural changes, therefore they must also have high balance and agility while doing rapid postural moves around the court.^[7,8]

With an average heart rate that is more than 90% of the player's maximum heart rate, badminton is an extremely demanding sport. The opponent's stroke of the shuttlecock determines its unusual trajectory. In order to predict their displacement throughout the match, players must execute high intensity intermittent actions while maintaining focus on the opponent and shuttlecock. This demands a specialized physical training in terms of

different movement controls. Strength, muscular endurance, power, speed, agility, flexibility, balance, and coordination are critical components for badminton players.

Although badminton being a non-contact sport, earlier studies that have been done reported that badminton injuries constituted of 1% - 5% of all sports injuries. Repeated rapid forward lunges during a badminton match created high stress loads especially on Achilles tendon and Patellar tendon in the dominant leg. Report was made that most of the badminton injuries (63.1%) occurred in lower extremities such as the knee (37.1%), ankle (28.3%), thigh (13.2%), heel (11.2%), toes (5.7%), and others (4.4%).^[9]

Dynamic balance refers to the capacity to perform a task while maintaining or regaining a stable position during locomotion. Balance is not only an important prerequisite for the performance of everyday tasks and the avoidance of falls but also for the successful performance of sport-specific skills in athletic population. It is evidenced that balance performance is task specific and therefore denoted as a skill and not an ability. [This procedure is directly related to the ability to control dynamic balance, which includes the ability to lunge, land steadily, and quickly adjust by change of direction (COD) of the body trunk.^[10]

A correlation between the capacity to maintain dynamic equilibrium and higher change of direction speed improved lunge control, improved jumping and running to smash.^[11,12,13]

Plyometric training (PT) entails movements that are connected to the stretch-shortening cycle (SSC), also known as the eccentric-concentric contraction cycle of the muscle (e.g., depth jump and continuous jump). PT is frequently used to train athletes because it helps increase their strength and jump performance,^[14] plyometric exercises have been used to improve muscle strength and explosive power in many facets of the sport. Eccentric motions in plyometric workouts are followed by concentric contractions of the same muscle group. A programmed plyometric workout is one that contains parts of plyometric exercise, which often involves repetitive leaping, running, and explosively modifying motion.^[15]

It has been utilized in several studies to test its effects on strength, agility, and sprinting prowess. Recent research has demonstrated that PT can have equivalent or even superior results than traditional resistance training in terms of enhancing athletes performance by enhancing their balance, power, agility, and strength.^[16,17]

For instance, it is found that six weeks of physical therapy dramatically increased the dynamic balance and knee proprioception of female badminton players, which ultimately helped to keep players from getting hurt.^[18]

Exercises performed on Swiss balls are nearly comparable to those performed with body weight, with the exception that they are slightly more difficult due to the unstable surface of the balls, which helps to increase the stability and strength of the muscles that stabilize the body.^[19]

Swiss balls spherical shape may aid to engage more stabilizing muscle motor units than standard floor exercises, which could improve overall balance^[21] and stability from the core muscles.^[20]

Swiss balls have been shown to activate specific areas of the brain stem, vestibular system, and cerebellum in addition to motor units, leading to improved body control, balance, and posture Strength training, balance training, physical fitness, flexibility training are just a few of the many uses for Swiss ball.^[21] The dynamic nature of Swiss ball exercises helps enhance flexibility, strength, balance, and coordination.

Muscle strength training can help to develop acceleration, strength, and limb power. These actions are elements that can aid in increasing dynamic balance.^[22]

MATERIALS AND METHODS

STUDY DESIGN: Randomized control trail design.

ETHICAL CLEARANCE and INFORMED

CONSENT: The study design and intervention were approved by the Ethical Committee of GSL Medical College and Hospitals, Rajamahendravaram (Annexure - I). The participants were explained by the investigator about the purpose of the study and information sheet was given to them. The subjects were requested to provide their consent for participation in study (Annexure - II). All participants signed the informed consent and the rights of the included participants have been secured.

STUDY POPULATION: college going badminton players who were willing to participate in the study were 100 subjects within the age group of above 18 years.

STUDY SETTING: the study was conducted in sports arena of GSL MEDICAL COLLEGE, Rajamahendravaram.

STUDY DURATION: The Study was conducted during a period of one year.

TREATMENT DURATION: Both the groups received intervention of three sessions per week for six weeks.

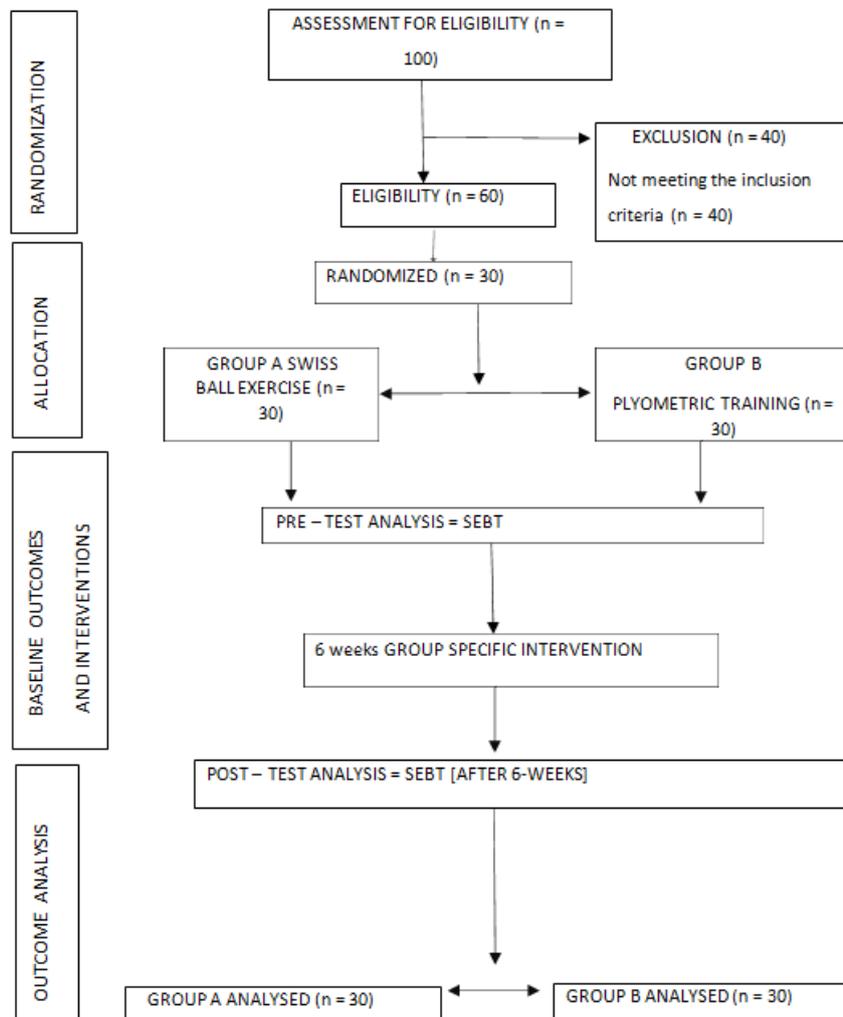
STUDY SAMPLING METHOD: Simple Random Sampling method.

SAMPLE SIZE: A total 100 students were screened for eligibility; out of which 60 college going badminton players were recruited and were explained about the

process and relevance of the study. Those willing to be voluntarily included in the study received informed consent and were asked to sign the forms. All the participants were consecutively randomized to either Swiss ball exercise and plyometric training group with

30 subjects in each group. The participants were given numbers 1 and 2. All those who received number 1 were included in group A who received Swiss ball exercise and all the participants who got the number 2 were allocated to group B who underwent plyometric training.

FLOWCHART



PROCEDURE

This is a randomized controlled trial study which includes 6 weeks protocol. Both male and female participants will be recruited from college of physiotherapy and GSL education institutes, Rajahmundry. The study is explained individually to the subjects who meet inclusion criteria after taking informed consent, the subjects will be divided into two groups by using coin toss method. Pre-test measures will be taken by using Star excursion exercise test [SEBT].

Subjects in the group A will receive Swiss ball exercises and group B will receive plyometric training. After completion of study duration post-test measurements will be taken after the procedure by star excursion exercise

test. based on post-test measurement.

SWISS BALL TRAINING: Here the group A subjects will receive Swiss ball exercise for 3 sessions for a week for six weeks the treatment time is 40 min each session will perform for 4 [Repetition maximum]RM with 3 sets after completion of each single set 2 min resting time will be given to the participants. Here the exercises given below.^[24]

- Swiss ball straight arm crunch
- Swiss ball alternate arm and leg extension
- Swiss ball squat
- Swiss ball shoulder bridge
- Swiss ball leg raise

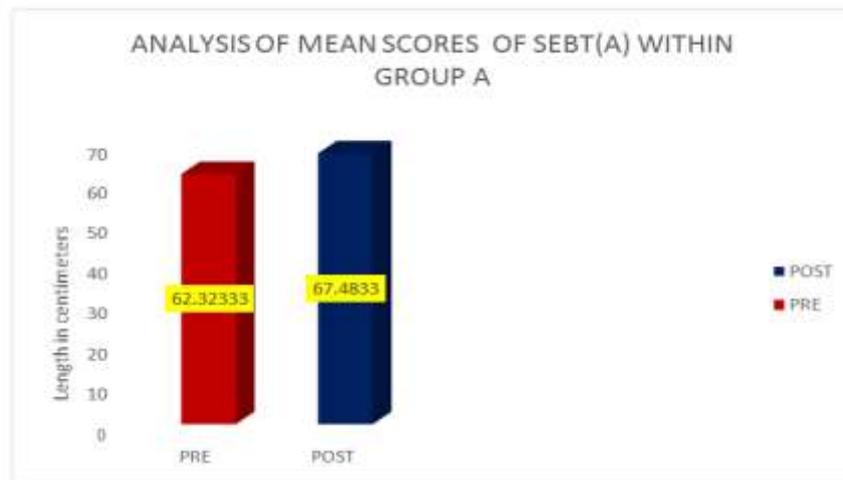
PLYOMETRIC TRAINING: The plyometric training will last for 6 weeks with 3 sessions per week Each session will last for 40 minutes, and the exercises will be performed for 3 sets with 4 RM. The participants will receive a 2-minute break in between each set. Here the exercises given below.

- Side to side ankle hops standing jump and reach front cone hops.

- Side to side ankle hops standing jump, lateral jump over barrier double legs hops.
- cone hops with 108 degree turn single leg bounding, lateral jump single leg.
- Diagonal cone hops hexagonal drill cone with change of direction sprint, double leg hops, lateral jump single leg.^[25]

Table 1: Analysis of Mean Scores of SEBT (A) Within Group A.

GROUP A		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT (A)	PRE - TEST	62.323	6.159365	0.000000	HIGHLY SIGNIFICANT
	POST - TEST	67.483	6.15116	547	



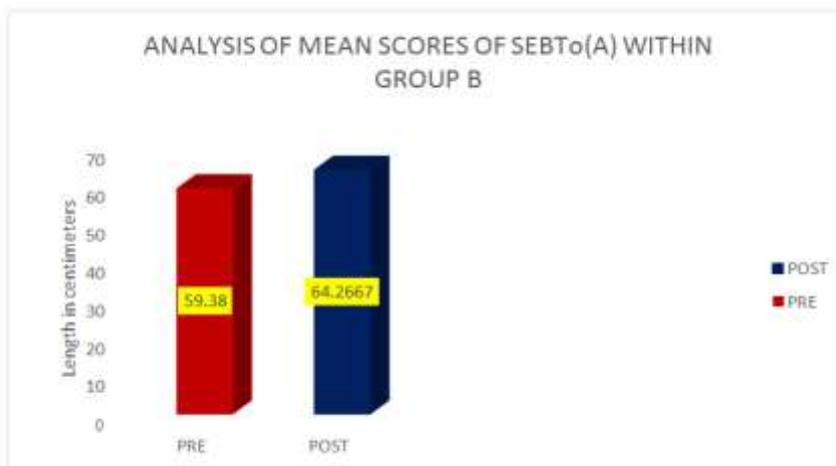
GRAPH - 1

RESULTS: The above table and graph shows that the mean score of SEBT (A) changes from pre-test to post-

test values within the group A were found to be highly significant.

Table 2: Analysis of Mean Scores of SEBT (A) Within Group B

GROUP B		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT (A)	PRE - TEST	59.38	4.134198	0.000000	HIGHLY SIGNIFICANT
	POST - TEST	64.266	3.92584	000765	



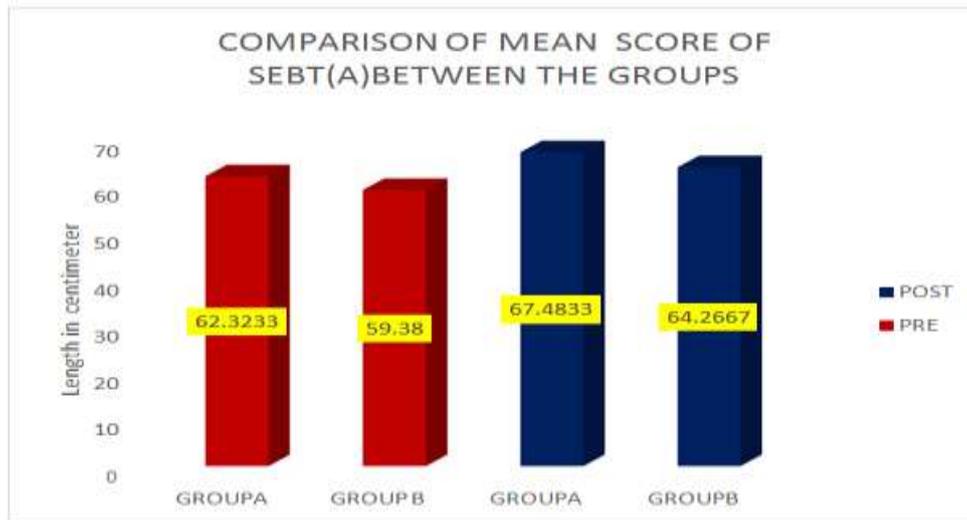
GRAPH - 2

RESULTS: The above table and graph shows that the mean score of SEBT (A) changes from pre-test to post-

test values within group B were found to be statistically highly significant (p<0.005)

Table 3: Comparison of Mean Score of SEBT (A) Between The Two Groups.

SEBT (A)		Mean	Std. Deviation	P- VALUE	INFERENCES
PRE-TEST	GROUP A	62.3233	6.159365	0.04384	INSIGNIFICANT
	GROUP B	59.38	4.134198		
POST-TEST	GROUP A	67.4833	6.15116	0.0	HIGHLY SIGNIFICANT
	GROUP B	64.2667	3.92584		

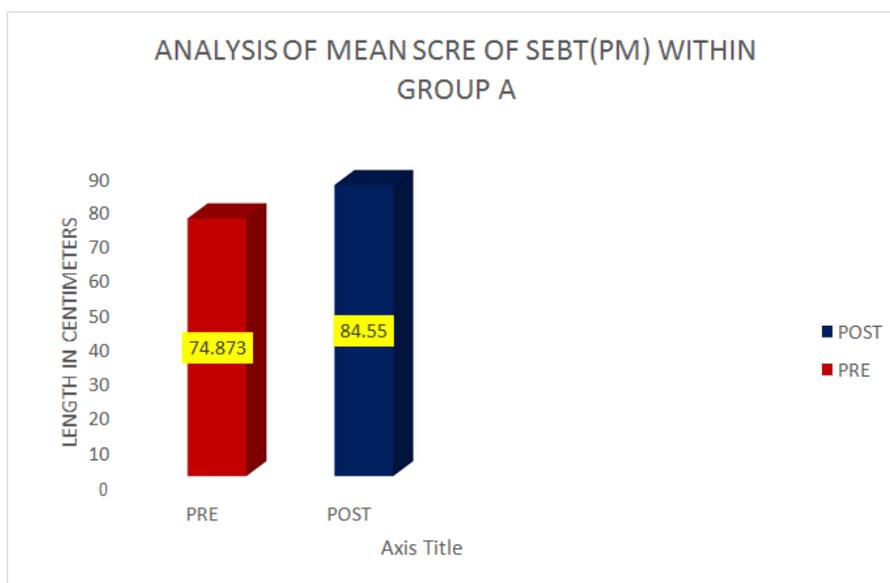


GRAPH – 3

RESULTS: The above table and graph shows that the mean scores of SEBT (A) from pre-test to post-test in between both groups to have been statistically significant.

Table 4: Analysis of Mean Score of SEBT (PM) Within Group A.

GROUP A		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT (PM)	PRE - TEST	74.873	5.672561	0.00000 001	HIGHLY SIGNIFICANT
	POST - TEST	84.55	5.67502		

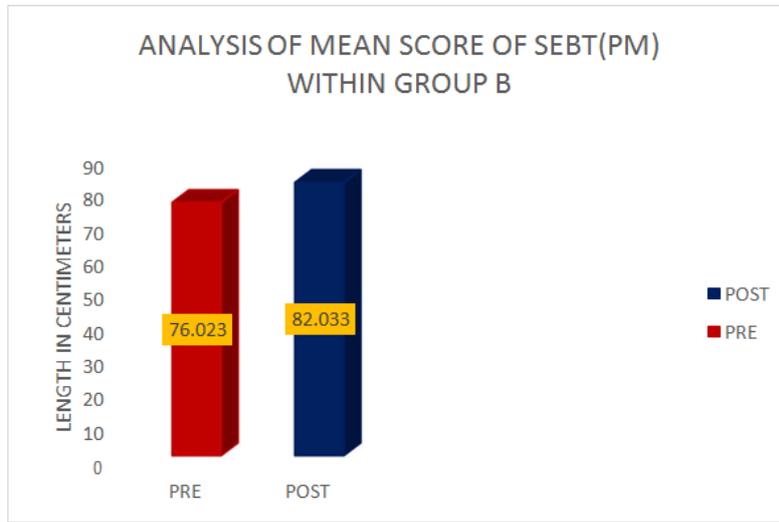


GRAPH – 4

RESULTS: The above table and graph shows the analysis of mean score of pre- tests to post- test of SEBT (PM) within group A found to be statistically significant.

Table 5: Analysis of Mean Score of SEBT (PM) Within Group B.

GROUP B		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT (PM)	PRE - TEST	76.013333	5.33464	0.00000001	HIGHLY SIGNIFICANT
	POST - TEST	82.0333	5.123237		

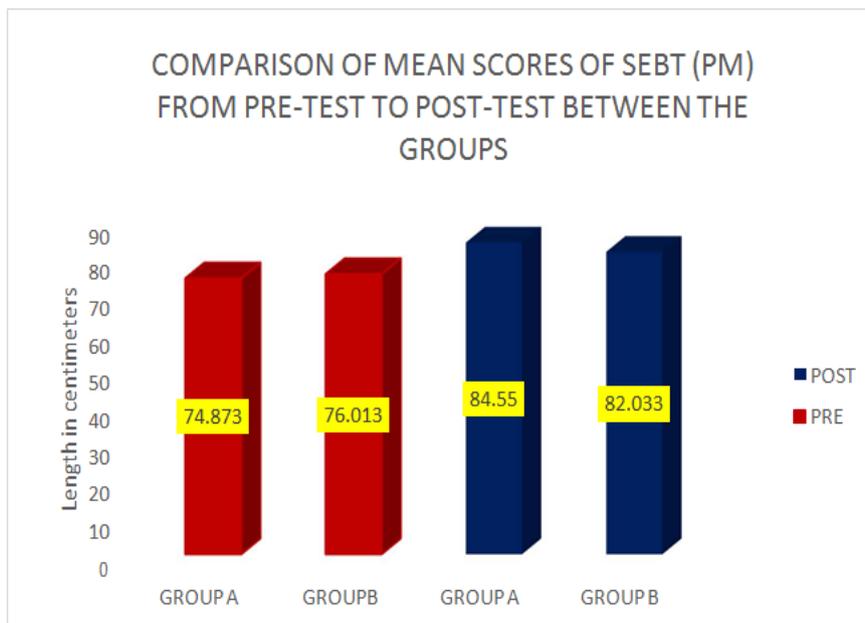


GRAPH – 5

RESULTS: The above-mentioned table and graph of the SEBT (PM) within the group B; that was found to denote the pre-test to post-test changes in the mean score be highly significant.

Table 6: Comparison of Mean Scores of SEBT (Pm) From Pre-Test To Post-Test Between The Groups.

SEBT (PM)		Mean	Std. Deviation	p-VALUE	INFERENCES
PRE-TEST	GROUP A	74.873	5.672561	0.33864463	INSIGNIFICANT
	GROUP B	76.013	5.33464		
POST-TEST	GROUP A	84.55	5.67502	0.03467	HIGHLY SIGNIFICANT
	GROUP B	82.033	5.12337		

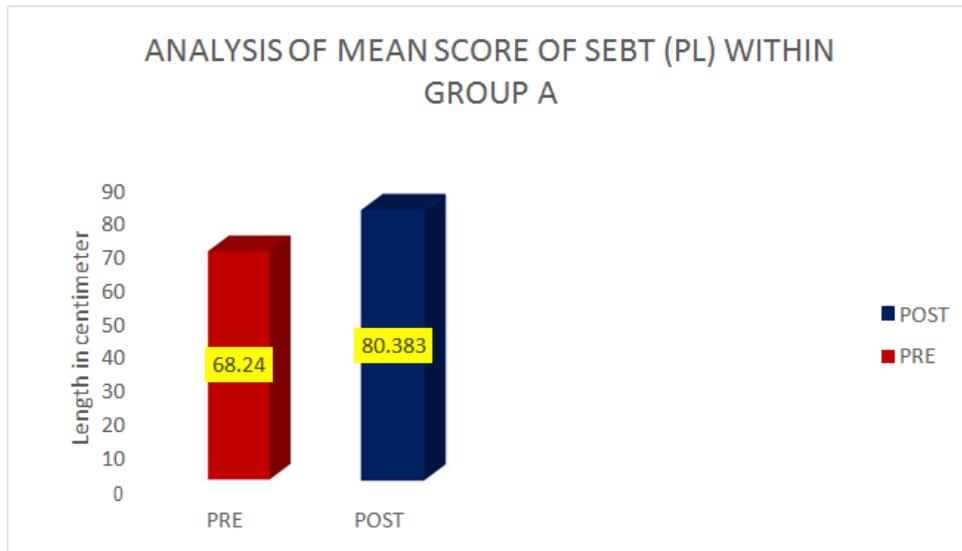


GRAPH – 6

RESULTS: the above table and graph mentions about between the groups have shown to be statistically significant. the mean score of SEBT (PM) from pre-test to post-test

Table 7: Analysis of Mean Score of SEBT (PL) Within Group A.

GROUP A		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT (PL)	PRE-TEST	68.24	4.614938	0.00000 00744	HIGHLY SIGNIFICANT
	POST – TEST	80.383	5.32867		

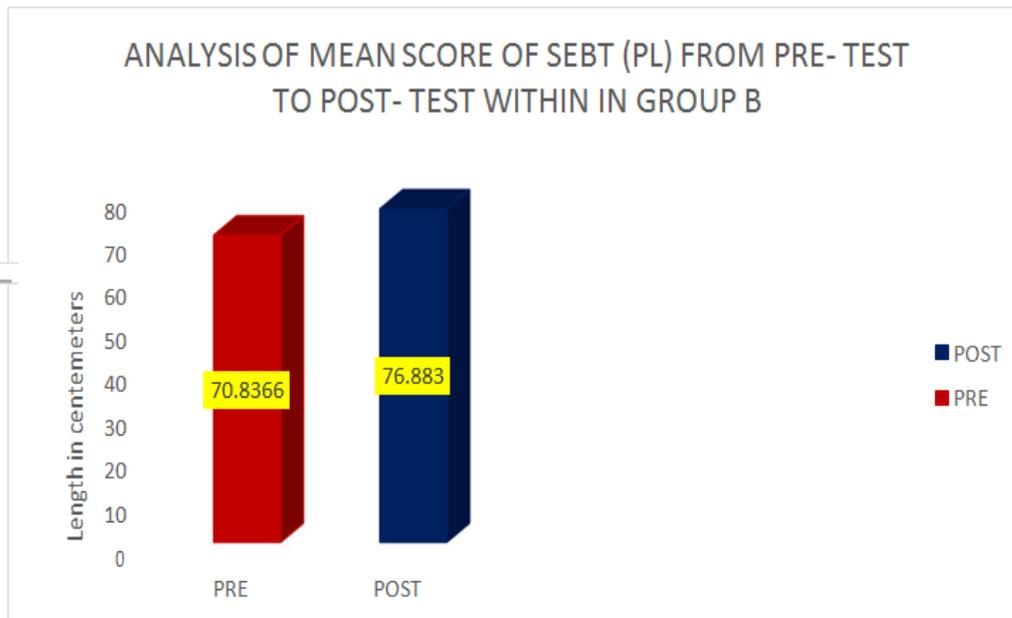


GRAPH – 7

RESULTS: The above-mentioned table and graph SEBT(PL) from pre-test to post-test within group A. show that there is statistically high significance in

Table 8: Analysis of Mean Score of SEBT (PL) from Pre- Test to Post-Test Within Group B.

GROUP B		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT (PL)	PRE - TEST	70.8366	4.743028	0.0000012 145	HIGHLY SIGNIFICANT
	POST-TEST	76.883	5.45998		

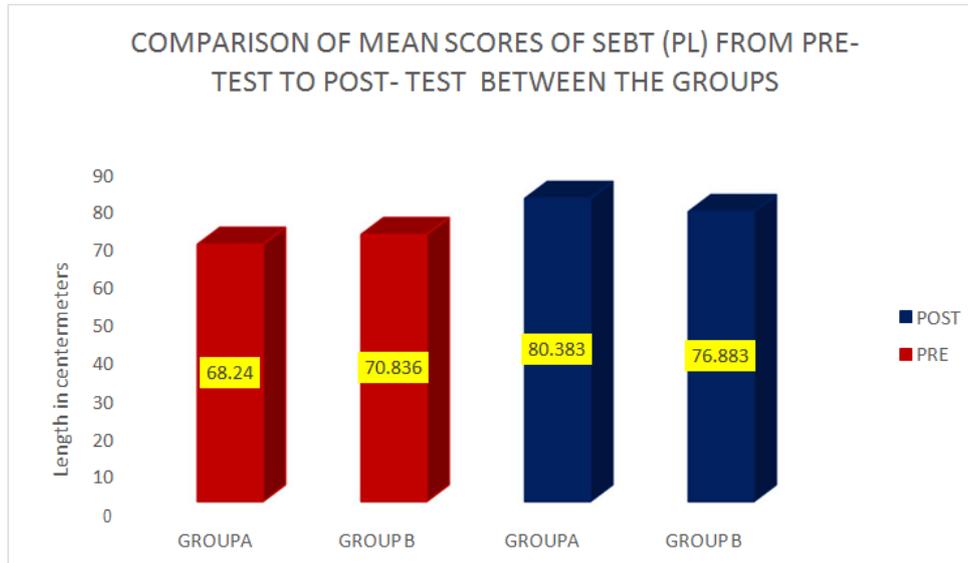


GRAPH – 8

RESULTS: The above given table and graph shows that the analysis of mean score of SEBT (PL) from pre-test to post-test within group B is statistically significant. Significant.

Table 9: Comparison of Mean Scores of SEBT (PL) from Pre Test To Post-Test Between The Groups.

SEBT (PL)		Mean	Std. Deviation	p- VALUE	INFERENCES
PRE- TEST	GROUP A	68.24	4.614938	0.02432 6124	INSIGNIFICANT
	GROUP B	70.836	4.743028		
POST- TEST	GROUP A	80.383	5.32867	0.005088	HIGHLY SIGNIFICANT
	GROUP B	76.883	5.45998		

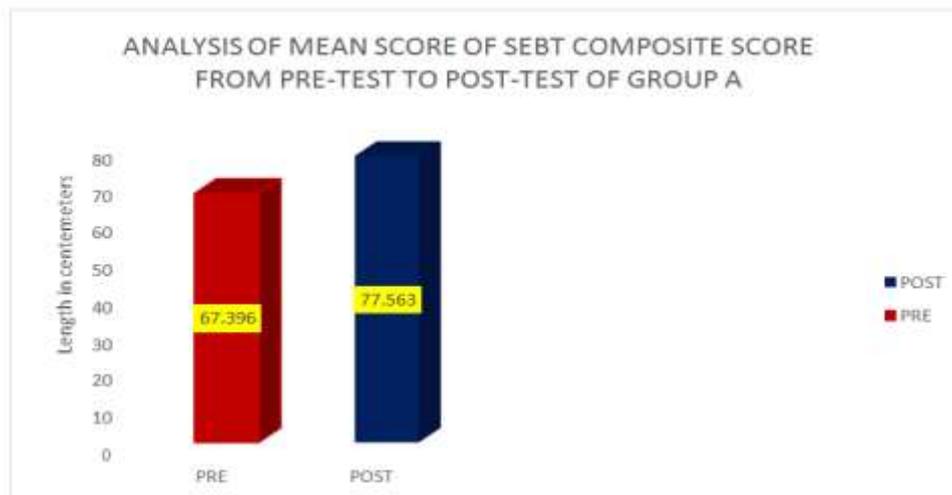


GRAPH - 9

RESULTS: The above-mentioned table and graph the groups from pre-test to post-test in SEBT (PL). represents the statistical significance is high between

Table 10: Analysis of Mean Score of SEBT Composite Score from Pre- Test To Post-Test of Group – A.

GROUP A		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT COM POSITE SCORE	PRE – TEST	67.396	5.9602283	0.000000 38763298	HIGHLY SIGNIFICANT
	POST – TEST	77.563	3.2366117		

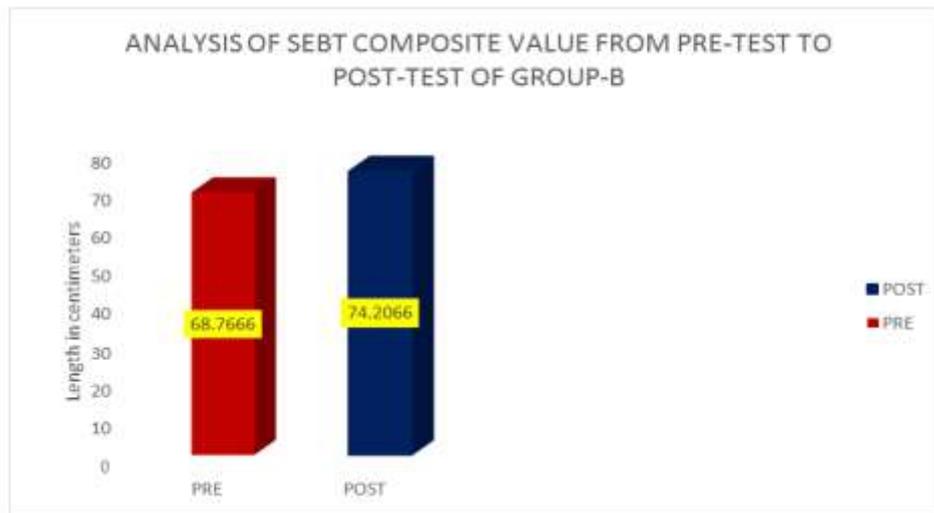


GRAPH - 10

RESULTS: The above-mentioned table and graph from pre-test to post-test of SEBT Composite Score shows that there is statistically significant difference within Group – A.

Table 11: Mean Analysis of SEBT Composite Value from Pre-Test To Post-Test of Group – B.

GROUP B		Mean	Std. Deviation	P VALUE	INFERENCES
SEBT COMPOSITE SCORE	PRE - TEST	68.7666	3.2316490	0.00000	HIGHLY SIGNIFICANT
	POST - TEST	74.2066	3.195824	0000001	

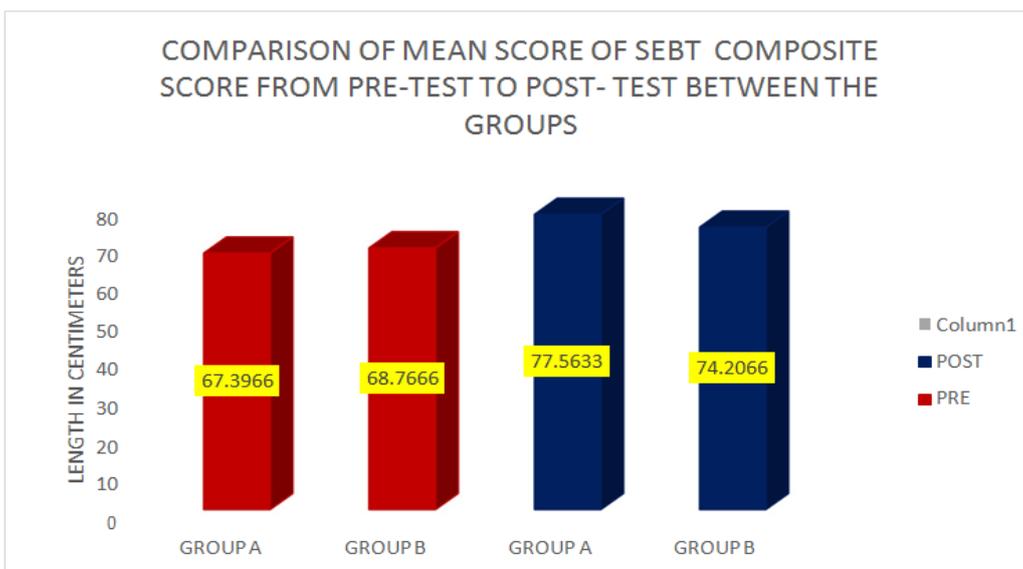


GRAPH – 11.

RESULTS: The above table and graph shows that there is highly statistically significant difference in Mean and SD of SEBT Composite Score from pre-test to post- test of Group – B.

Table 12: Comparison of Mean Score of SEBT Composite Score from Per-Test To Post-Test Between The Groups.

SEBT COMPOSITE SCORE		Mean	Std. Deviation	P VALUE	INFERENCES
PRE- TEST	GROUP A	67.39666	5.960228	0.25743	INSIGNIFICANT
	GROUP B	68.7666	3.23164	1688	
POST- TEST	GROUP A	77.5633	3.236611	0.00005	SIGNIFICANT
	GROUP B	74.2066	3.195824	3839	



GRAPH – 12.

RESULTS: The above-mentioned table and graph depicts that there is high statistically significant difference in the SEBT Composite Score from pre-test to post-test between both the groups.

DISCUSSION

The main purpose of this study was to evaluate the effectiveness of Swiss ball exercise and plyometric Training on improvement of Dynamic Balance in college going badminton players. In this study, subjects were assessed for Dynamic Balance using the outcome measures Star Excursion Balance test. sixty subjects were divided into two groups and group-A (n=30) received Swiss ball exercise and group-B (n=30) received plyometric Training, who underwent six-week exercise training program for Three sessions per week. Assessment was done before and after six weeks program.

By the end of the six weeks training program, the subjects of Group – A who received Swiss ball exercise had significantly improved results in Dynamic Balance which showed changes in outcome measures SEBT Composite mean score ($p = 0.0001$), Group – B who received plyometric Training also showed significant results in SEBT composite score ($p = 0.0001$).

The results of the study implied that there is a statistically significant improvement in both of Swiss ball exercise and plyometric Training program to effectively bring changes in both outcome measures, SEBT in college going badminton players.

Lu Z, Zhou L et al The effect of six weeks of combined plyometric and balance training on the dynamic balance and quickness performance of elite badminton players was the subject of his study. The purpose of the study was to find out how professional badminton players' dynamic balance and quickness were affected by plyometric and combined balance training. After putting in their voluntary time, sixteen of the best male badminton players were randomly assigned to a balance-plyometric test.^[26]

This study hypothesized around the concept that Swiss ball exercise will be more effective in improving dynamic balance than plyometric training. The study is supported by Morzia Khatoon et al who stated that six weeks of Swiss ball exercise training and plyometric training were equally effective in promoting dynamic balance in elite badminton players.^[27]

Betül Sekendiz et al had done a study on Effects of Swiss-ball core strength training on strength, endurance, flexibility, and balance in sedentary The purpose of this study was to investigate the effects of Swiss-ball core strength training on trunk extensor (abdominal)/flexor (lower back) and lower limb extensor (quadriceps)/flexor (hamstring) muscular strength, abdominal, lower back and leg endurance, flexibility and dynamic balance.^[28]

Aksen-Cengizhan, Pelin et al had done a study on A comparison between core exercises with

TheraBand and Swiss Ball in terms of core stabilization and balance performance. Core exercises include exercises to train muscles that control and stabilize the movements of the abdomen, waist, and hip. He explained that the control and balance of the body are increased. Exercises on unstable surfaces increase the level of muscle activity, and by using elastic resistance tools, one or more joints can be simultaneously and efficiently trained and to compare core exercises with TheraBand and Swiss Ball in terms of core stabilization and balance performance. According to the study core stability exercise can strengthen the body's deep sensory perception, which will improve dynamic balance. They looked into how swiss ball workouts, which focused on strengthening the trunk muscles, particularly the lumbosacral area, affected the dynamic balance of healthy individuals. They found that the balance improved very much, which is consistent with the findings of the current investigation. Here the author concluded that the dynamic balance in the players which was given by the author can improve the dynamic balance very significantly.^[29]

Eltanahi nagla et al had done a study on Effect of Swiss ball exercises on some physical and physiological variables and their relationship with kata performance level. The present work aims to study the effect of Swiss ball exercises on the abdominal, back and leg muscles strength, hip and spine flexibility, static and dynamic balance in badminton players. For trunk control to offer a firm basis for balance control, the adequate sensori motor skill is necessary. Exercises for trunk stabilization on unstable surfaces have been demonstrated to increase.^[30]

CONCLUSION

The present study concluded that six weeks program of Swiss ball exercise and plyometric training were shown to be statistically significant in improving dynamic balance in college going badminton players. However superior significant improvement in outcomes were seen in group-A which received Swiss ball exercise.

ACKNOWLEDGEMENT

I am grateful to **Dr. Ganni Bhaskara Rao, Chief Patron**, G.S.L Educational Institutions, Rajamahendravaram, for his valuable support and help in permitting me to take the subjects from G.S.L Medical College & General Hospital.

I take this pleasant and unique opportunity to express my deep sense of gratitude and offer my most sincere and humble thanks to my **Principal** and my teacher and esteemed research Guide **Dr. P.V. Surya Prakash MPT (Sports)** who helped me to shape my dissertation well right from the beginning and for allowing and supporting me to undertake the study and for the expert guidance, affectionate nature and friendly attitude.

REFERENCE

1. Arora M, Shetty SH, Khedekar RG, Kale S. Over half of badminton players suffer from shoulder pain: is impingement to blame? *J Arthrosc Joint Surg*, 2015; 2(1): 6-33.
2. Phomsoupha, M.; Laffaye, G. The science of badminton: Game characteristics, anthropometry, physiology, visual fitness and biomechanics. *Sports Med*, 2015; 45: 473–495. [CrossRef] [PubMed]
3. Cabello Manrique, D.; González-Badillo, J.J. Analysis of the characteristics of competitive badminton. *Br. J. Sports Med*, 2003; 37: 62–66. [CrossRef] [PubMed]
4. Alam, F.; Chowdhury, H.; Theppadungporn, C.; Subic, A.; Khan, M. Aerodynamic properties of badminton shuttlecock. *Int. J. Mech. Mater. Eng*, 2009; 4: 266–272.
5. Cabello Manrique D, González-Badillo JJ. Analysis of the characteristics of competitive badminton. *Br J Sports Med*, 2003 Feb; 37(1): 62-6. doi: 10.1136/bjism.37.1.62. PMID: 12547746; PMCID: PMC1724585.
6. Cuğ, Mutlu. "Effects of swiss ball training on knee joint reposition sense, core strength and dynamic balance in sedentary collegiate students, 2012; 28: 62-49.
7. Shariff, A.H.; George, J.; Ramlan, A.A. Musculoskeletal injuries among malaysian badminton players. *Singap. Med. J.*, 2009; 50: 1095–1097.
8. Hong, Y.; Wang, S.J.; Lam, W.K.; Cheung, J.T.M. Kinetics of badminton lunges in four directions. *J. Appl. Biomech*, 2014; 30: 113–118. [CrossRef] [PubMed]
9. Rouissi, M.; Haddad, M.; Bragazzi, N.L.; Owen, A.L.; Moalla, W.; Chtara, M.; Chamari, K. Implication of dynamic balance in change of direction performance in young elite soccer players is angle dependent. *J. Sports Med. Phys. Fit.*, 2018; 58: 442–449. [CrossRef] [PubMed]
10. Hrysomallis, C. Relationship between balance ability, training and sports injury risk. *Sports Med.*, 2007; 37: 547–556. [CrossRef]
11. Irawan D. Six Weeks Progressive Plyometrics Training on Badminton Player's Agility. In *Health Science International Conference (HSIC 2017)*, 2017 Oct. (pp. 18- 21). Atlantis Press.
12. Lu Z, Zhou L, Gong W, Chuang S, Wang S, Guo Z, Bao D, Zhang L, Zhou J. The Effect of 6-Week Combined Balance and Plyometric Training on Dynamic Balance and Quickness Performance of Elite Badminton Players. *Int J Environ Res Public Health*, 2022 Jan 30; 19(3): 1605. doi: 10.3390/ijerph19031605. PMID: 35162627;
13. PMCID: PMC88355271. Arora M, Shetty SH, Khedekar RG, Kale S. Over half of badminton players suffer from shoulder pain: is impingement to blame? *J Arthrosc Joint Surg*, 2015; 2(1): 6-33.
14. *Environ Res Public Health*, 2022 Jan 30; 19(3): 1605. doi: 10.3390/ijerph19031605. PMID: 35162627; PMCID: PMC8835527.
15. Woodward M. *BWF Coach Education Level 2.1th ed.* Kuala Lumpur: Badminton World Federation, 2013. 247 p.
16. Anderson, K.G. & Behm, D.G. The impact of instability resistance training on balance and stability. *Sports Medicine*, 2005; 35(1): 43-53.
17. Behm, D.G., Drinkwater, E.J., Willardson, J.M. & Cowley, P.M. The use of instability to train the core musculature. *Applied Physiology Nutrition and Metabolism-Physiologie Appliquee Nutrition Et Metabolisme*, 2010; 35(1): 91- 108.
18. Carter, J.M., Beam, W.C., McMahan, S.G., Barr, M.L. & Brown, L.E. The effects of stability ball training on spinal stability in sedentary individuals. *Journal of Strength and Conditioning Research*, 2006; 20(2): 429-435.
19. Stanton R., Reaburn, P.R. & Humphries, B. The effect of short-term Swiss ball training on core stability and running economy. *Journal of Strength and Conditioning Research*, 2004; 18(3): 522-528.
20. Carrière, B. *The Swiss ball: theory, basic exercises and clinical application.* Champaign, IL: Human Kinetics, 1998.
21. Akuthota V, Ferreiro A, Moore T, Fredericson M. Core stability exercise principles. *Curr Sports Med Rep.*, 2008; 7(1): 39–44.
22. Watkins, S. Get on the ball, the "birth ball" that is! *International Journal of Childbirth Education*, 2001; (16): 17-19.
23. Ozmen T, Aydogmus M. Effect of core strength training on dynamic balance and agility in adolescent badminton players. *Journal of bodywork and movement therapies*, 2016 Jul 1; 20(3): 565-70.
24. Alikhani R, Shahrjerdi S, Golpaigany M, Kazemi M. The effect of a six-week plyometric training on dynamic balance and knee proprioception in female badminton players. *The Journal of the Canadian Chiropractic Association*, 2019 Dec; 63(3): 144.
25. Churi AB, Varadharajulu G. Effect of Core Strengthening and Conditioning Programme on Badminton Beginners. *Indian Journal of Forensic Medicine & Toxicology*, 2020 Jul 1; 14(3).
26. Phomsoupha M, Laffaye G. The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics. *Sports medicine*, 2015 Apr; 45(4): 473-95.
27. Fahlström M, Björnstig U, Lorentzon R. Acute badminton injuries. *Scandinavian journal of medicine & science in sports*, 1998 Jun; 8(3): 145-8.
28. Shariff AH, George J, Ramlan AA. Musculoskeletal injuries among Malaysian badminton players. *Singapore medical journal*, 2009 Nov 1; 50(11): 1095.
29. Ramachandran AK, Singh U, Ramirez-Campillo R, Clemente FM, Afonso J, Granacher U. Effects of plyometric jump training on balance performance in healthy participants: a systematic review with meta-analysis. *Frontiers in physiology*,

2021; 1760.

30. Sheppard JM, Young WB. Agility literature review: Classifications, training and testing. *Journal of sports sciences*, 2006 Sep 1; 24(9): 919-32.
31. Huang, M.T., Lee, H.H., Lin, C.F., Tsai, Y.J., Liao, J.C. How does knee pain affect trunk and knee motion during badminton forehand lunges? *J. Sports Sci.*, 2014; 32(7): 690-700.
32. Sighamoney R, Kad R, Yeole UL. Effect of core strengthening on dynamic balance and agility in badminton players. *International Journal of Physical Education, Sports and Health*, 2018; 5(1): 86.
33. Latorre Román PÁ, Villar Macias FJ, García Pinillos F. Effects of a contrast training program on jumping, sprinting and agility performance of prepubertal basketball players. *Journal of sports sciences*, 2018 Apr 3; 36(7).