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# The Effect of Core Stability Training on Dynamic Balance and Smash Stroke Performance in Badminton Players

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**Abstract:** The researches which investigated the effects of core training on skill performance for badminton players are in sufficient. The current study aimed to examine the effects of core stability training on dynamic balance and smash stroke velocity and accuracy performance. Twenty badminton players under 19 years were divided into two groups, core training group ($n$ = 10) and control group ($n$ = 10). Core stability training group completed 8 weeks training programme, while control group did only their badminton traditional training. The effectiveness of core stability training intervention was assessed by performing core stability tests with four positions, dynamic balance test and forehand smash stroke performance test. Significant improvement was obtained only in the training group for core muscle endurance, total reached distance of three directions in star excursion balance test and smashing velocity and accuracy variables ($p < 0.05$). Consequently, eight weeks core stability training provides an improvement for maintained optimum lower limbs dynamic balance and increased the performance level of smash stroke in young badminton players.

**Keywords:** Core Strength, Core Exercise, Balance, Velocity, Accuracy, Smash

## 1. Introduction

Badminton is considered as one of the most popular racket sports over the world, in which two or four opposing players strike a shuttlecock over a dividing net between them to score a point. The overhead technique is one of the three main categories of badminton strokes, which divided into three strokes drop, clear and smash. In addition, the forehand and backhand overhead strokes commonly are a fundamental demand to play badminton.

Badminton players need to conduct various movement patterns during the game including specialized twists, jumps, footwork, and swings to strike the shuttlecock and keep it moving back and forth on the court. Thus, the game is characterized by a changing temporal structure with actions of short period and high or medium intensity coupled with a short resting times [1].

Smashing performance is a key factor to winning points during the badminton game and commonly used from different positions and places on the court. Often, smash stroke is the execution that determines the advantage of one player over another during the game and probably is the most overused stroke among the younger players, with the efficiency of a stroke that primarily influenced by two tasks: smashing velocity and accuracy [2, 3].

Badminton requires a specific physical conditioning in terms of motor and action controls; coordinative variables such as reaction time, foot stepping and static or dynamic balances, which are essential motor demands in this sport [1, 4]. Therefore, badminton players need enough strength and a high level of dynamic balance during the rapid postural movements around the court.

[5] Suggested that player who performs overhead smash stroke must go through various movement and direction patterns to reach in the optimum hitting point with stretched entire body, which means that upper body and smashing arm will be in the optimum coordinated stretching position. Moreover, the core musculature acts as a connecting bridge between upper and lower extremities limb in overhead athletic endeavors such as smashing in badminton or throwing in handball sport, and plays an important role with regard to transferring energy from the proximal to the distal body segments [6, 7].

Core stability is defined in athletic settings as the optimum production, which can transfer and control the force from the center of the body to the limbs, through stabilization of the position and motion of torso [8]. Also [9] described it as a central motor control of the lumbar-pelvic-thigh to maintain the stability of the core region against different postural and external forces.

Generally referred to as the core area, these overall and local muscles which constantly working to maintain posture and assist in changing postures and dynamic movements. [10] Described the role of core muscles as to, transfer force and doing a link between upper and lower extremities, help passive existence protect and support the spine.

Previously, core stability exercises were widely used for reducing the injuries of the low back and lower extremities [9, 11, 12]. Recently, core stability training has been purported to improve player performance [7, 13-15], but the previous studies have not supported these claims in badminton sport.

Studies in badminton sport, have been shown an important role of core stability to improve performance; [16] emphasized on the specific needs requires of strength to passes from ankle-knee-badminton-core area-fingers-wrist- in skills of badminton, which reflects the general system performance in this sport. In addition confirmed that, it's very difficult to maintain the smooth power delivery if there are any link problems in the kinematic chain during the skill performance in badminton such as smash stroke.

In addition, a core stability exercises are an essential fitness component of any racket sports player, particularly for badminton players during smashing the shuttlecock smash through the game. In badminton, the non-contact technique when player landing from the jump after smash overhead stroke, sometimes caused injuries for the knee which probably occurs as a result of strength loose or stability weakness and balance. In this context, [12] observed that poor trunk flexion strength increase the knee valgus moment during the landing with single leg following an overhead stroke skill in badminton players.

Postural control or balance defined as an ability to maintain a base support with minimal movement actions and dynamically to perform a motor task while maintaining a stable position. Indeed, balance is the ability to maintained dynamic integration of interior and exterior forces during motor action tasks [13, 17].

Balance is usually considered a static process, and in fact is a comprehensive, dynamic three-dimensional process contains multiple neural pathways. Badminton is a dynamic equilibrium process which involves loss of balance in the air to restore balance after landing. Thus, players need body coordination and dynamic balance [16].

In context of impaired trunk control and weak balance ability, previous studies have confirmed that efficient neuromuscular control of trunk stability and a perfect trunk muscle recruitment patterns are vital factors for the control of spinal load in relation to given task or position during the body movement [18, 19].

Thus, a particular attention paid to the core region because it serves as a muscular corset that works as a unit to stabilize the body and spine during all actions with or without limb movement, and this processes often is an evident during smashing a shuttlecock in badminton. In this concerning, [8] confirmed that core stability and strength endurance are an important components to maximizing dynamic balance and movements athletic function with upper or lower limb.

In considering the above background, it is proved that both core stability and dynamic balance are essential in badminton sport. However, lack studies highlighted into how the balance linked with core strength training in badminton training sessions to improving the complex tasks of important badminton skills.

There are some studies investigated how the important physical fitness of players improved by the core stability and balance training programm. In badminton, [15] reported that 6 weeks core stability training program improved balance and muscle core endurance in adolescent badminton players, however no decreases mean times observed in agility test. There are also studies examined how core stability training can be reduce the risk of injury and improve balance control, and confirmed that trunk muscle fatigue led to decrease dynamic stability of trunk region and loss of balance control. For example, study of [19-22] confirmed that badminton training sessions should include core strength exercise to reduce the knee pain which support the trunk and knee motions during forehand lunges. Also study of [23] suggested that the trunk's internal rotation in a jump smash occurs when the player drives the forearm to swing upward to contact the shuttlecock with the racket frame and this emphasized that core stability exercises are vital to improve this movement pattern and maintain balance for badminton players.

In this case, the links between core strength training and dynamic balance could improve both important components for badminton players in one training program. In addition, the outcome benefits after 8 weeks training could affect the overhead smash stroke velocity and accuracy performance. Consequently, this study will propose to identify if U 19 badminton players in an 8-week core stability training program will cause a significant difference in dynamic balance and forehand smash stroke performance.

# 2. Methods

### *2.1. Participants*

Twenty male badminton players participated in the current study; all players were members of young teams (U 19) from two clubs (El Shams and Tala'ea El-Gaish SC), which competed in the Egyptian badminton league. The badminton players had at least 6 years of badminton training and 4 years of a competitive experience at the national league level. The anthropometric, training and competitive experiences presented in (Table. 1) as (mean ± SD).

The participants were divided randomly into two groups;

the core stability training group (CSG, $n$ = 10) and the control group (CG, $n$ = 10). Based on the accordance with the Helsinki Declaration, the subjects fully informed before they participated in the current study regarding the experimental procedures and the potential risks. All players were healthy without any history of injuries.

***Table 1.*** *Anthropometric and training characteristics of participants.*

| Variables | CSG | CG | *t-test (p-value)* |
|---|---|---|---|
| Age (years) | 18.20 ± 0.79 | 18.10 ± 0.74 | 0.77 |
| Height (meters) | 1.76 ± 0.02 | 1.73 ± 0.03 | 0.60 |
| Weight (Kilograms) | 72.70 ± 4.05 | 73.37 ± 3.14 | 0.68 |
| Body mass index (Kg/m$^2$) | 23.54 ± 1.09 | 24.46 ± 0.97 | 0.62 |
| Training experience (years) | 8.40 ± 0.61 | 8.20 ± 0.79 | 0.54 |
| Competitive experience (years) | 5.20 ± 0.48 | 5.05 ± 0.55 | 0.53 |

***Notes:*** CSG = Core stability training group ($n$ = 10), CG = Control group ($n$ = 10).
t-test differences between groups were not significant ($p > 0.05$)

### *2.2. Procedures*

The participants completed the core stability training 2 times per week on the same time of their scheduled team training. The duration of the core training session was approximately 25 minutes for 8 weeks with a total of 16 sessions. All players during the core stability training programme were observed while performing the given duties of core stability exercises to maintain that exercises were performed correctly or not.

The participants were instructed with the testing protocol sessions and were performed the tests before and after the 8 weeks of the core stability training programme. The tests were performed in the same order and scheduled at 03:00 p.m clock.

The subjects performed 15 min of warm-up which consisted of stretching and mobility exercises and either pretest or posttest session, every test phase performed with 2 separated days. On the first test day, the Star Excursion Balance Test (SEBT) was performed to assess the dynamic balance of players followed by the core stability tests. On the second day, the forehand smash stroke performance test was conducted to assess the smashing velocity and accuracy of badminton players when performs the smash overhead stroke.

Before each testing day, the players were instructed on how they doing each test and allowed to perform a familiarization period, and after three minutes of this period, they underwent to the tests order. The rest period between the (SEBT) test and the core stability tests was at least 5 minutes and all players told to do their maximum effort throughout each test.

### *2.3. Measurements*

#### *2.3.1. Star Excursion Balance Test (SEBT)*

The (SEBT) test used to assess dynamic balance of badminton players and conducted to the exact following protocol as modified by [24, 25]. Every player stands with one dominant leg without his sports shoe and tries to reach as far as possible with his non-dominant leg in each of 3 directions while maintaining the dominant leg stance. The reached 3 directions were orientated as anterior to the apex, (medial) aligned at 135º to the posteromedial and posterolateral.

The selected directions marked with tape on the soft ground surface. The dominant leg of each player determined by asking him which leg he uses during the jumping take-off when performs an overhead smash stroke. The (SEBT) score calculated by the non-dominant leg reached distance in centimeters which standardized on the leg length by dividing each distance by the leg length and then multiplying by 100 [26], and the normalized value defined as the percentages of the excursion distance and its relation to the leg length. The leg lengths measured from the anterior superior iliac spine to the distal tip of the medial malleolus with a tape measure. The SEBT has been shown to possess high intra- and inter-tester reliability (ICCs equal 0.81and 0.96) [24, 27].

#### *2.3.2. Core Stability Tests*

Core stability tests used to assess the core strength endurance of badminton players. Each player tested by four separate position tests which defined as (ventral, lateral-left, lateral-right and dorsal) as modified by [28, 29]. The player movement speed rhythm was dictated by launching free metronome software on the laptop, and the rhythmic pattern of the metronome was tricked a signal sound second by second. Time was recorded in seconds using a stopwatch and the rest recovery time between a two core tests was 5 minutes. The test was discarded when the player failed to maintain the dictated movement speed rhythm or was unable to hold the required position as he instructed before. The score is the length of time to the exhaustion for every core test position which defined as a variable to represent the core stability of the badminton players and used for statistical analysis. The sum of length time to the exhaustion for all core stability tests was described as a variable to represent the player ability level of core strength as suggested by [30] and consisted with [11] who reported that core muscle work together to achieve spinal stability during movement tasks. Before the begging of core stability test, players perform a warm-up for the muscles with some low-intensity activity such as light jogging or walking. The detailed core tests were illustrated in the following figure below as designed by [28].

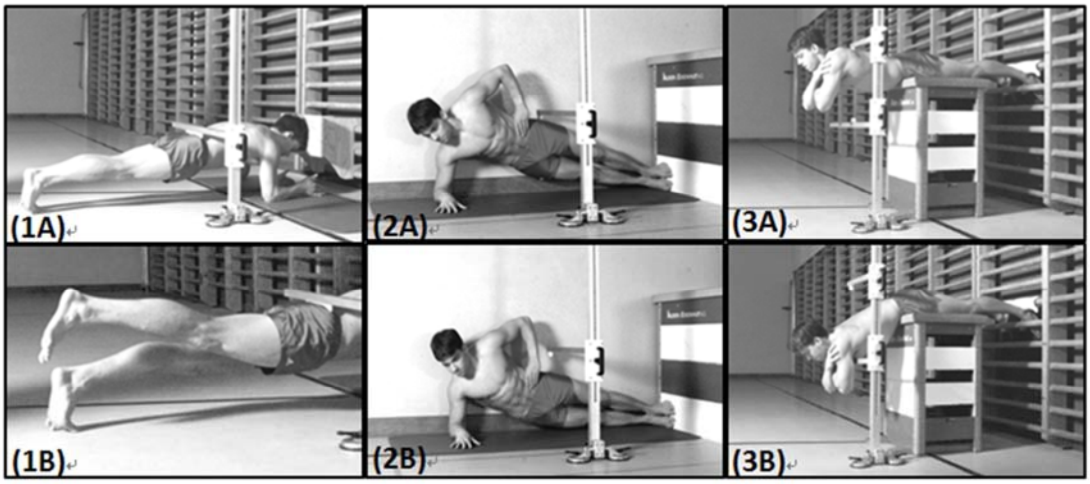


***Figure 1.*** *Core stability tests.*

***(i). Ventral Core Stability Test***

For the ventral test position, player lays his face down in a front plank position with his forearms and toes on a gym mat on the floor, and with a straight line of head, shoulders, back, hip, and legs. On command, the player was asked to contact their head with a board which placed on the wall in the front of him. When a ventral test begins, the player asked to raise his feet separately and in alternative movement up and down for approximately 2 to 5 cm and according to a given metronome signals. The test was finished when straight body on plank position could no longer be maintained. Time was recorded with a stopwatch in seconds (Photo 1A, 1B).

***(ii). Lateral (Left and Right) Core Stability Tests***

For the lateral test position either left or right side test, player lays on his side plank position with elbow on the gym mat with extended legs together. On command, the player was asked to place his non-dominant hand on his hip, left the hips off the mat and contact with his body with the wall. When a lateral test begins, the player asked to lower his hip down and then raise his hip up to the initial position according to a given metronome signals. The test was finished when straight body on side plank position could no longer be maintained or the body don't contact with the wall during the test. The player tested two times in this position; the first from right side plank position and the second at left side plank position. Time was recorded with a stopwatch in seconds (Photo 2A, 2B).

***(iii). Dorsal Core Stability Test***

For the dorsal test position, player lays his face down on a physio table in a straight horizontal line with an extended upper body out over the end of the table front edge. The player pelvis, hips, and knees were in a flat position on the physio table and both arms folded across the chest with hands placed on the opposite shoulders. The feet must be secured by a padded strap or held by the examiner. On command and according to a given metronome signals, the player was asked to flexes his upper body by moving downward to angle of 30º and then return upward to the initial position. The test was finished when a straight horizontal line position could no longer be maintained. Time was recorded with a stopwatch in seconds (Photo 3A, 3B).

***2.3.3. Forehand Smash Stroke Performance Test***

The forehand smash stroke performance test established to analyze both, strike velocity and accuracy as a modified by ARISTO project [31]. The dimension of a square target (60 × 60 cm) was fixed on the upper right corner of the single badminton court using a different colored tape. The square target colors marked with three different colors (red, blue and yellow); red color 3 point, blue 2 point and yellow 1 point and each color target size was 20 cm width and 60 cm length.

A radar gun (Bushnell Velocity Speed Gun, USA) was used to measure strike velocity. The Bushnell radar gun was set on peak mode to detect the maximal smashing velocity, between the range of 16 and 177 $km.h^{-1}$. Before the beginning of smash test, the radar gun was calibrated in accordance with the manufacturer's instructions manual. The radar gun was positioned 2 meter behind the player strike area and outside the back-line of the badminton court. The radar gun was aligned with approximate height of shuttlecock smashing release ~2 meters and located in the straightforward direction to the colored square mark in the upper right corner of the other court which shuttlecock landed in.

After a completed warm-up period with about 10 - 15 minutes, the subjects were asked to perform 10 maximum forehand smash strokes interspersed by 5 - 10 second rest within the smashing strikes, which is based on specific demands of badminton players during competitive (3, 37). A good investigator stood directly in the right service court (on black point) and behind the left service court which colored target was in. The investigator plays 10 forehands to the player who stood on (small red start point) which fixed in the right service court of opposite court; when the forehand played from the investigator the player starts to take his ready position and moving backward to smashing the shuttlecock approximately from a long service line area in singles court and toward the colored targets in opposite court (Figure 2).

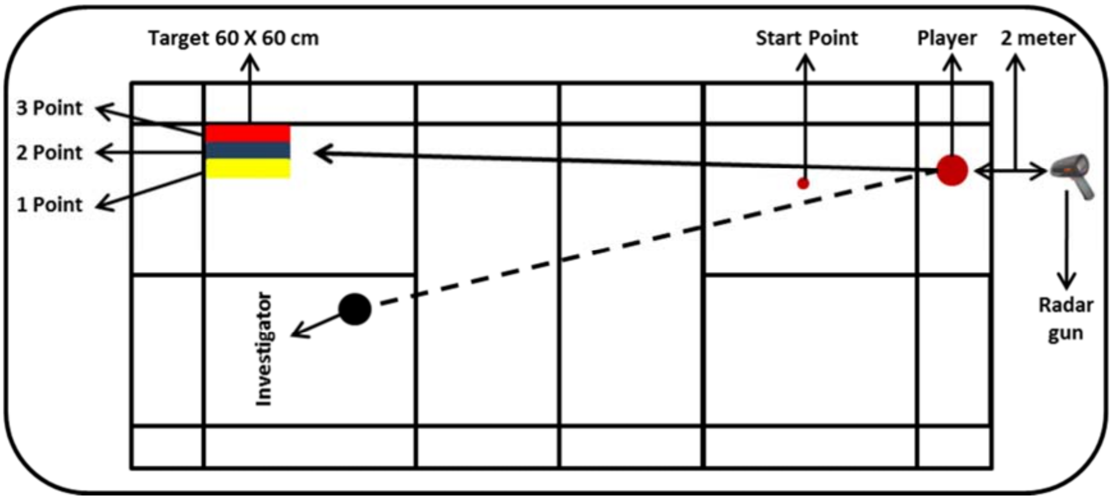


***Figure 2.*** *Forehand Smash Stroke Performance Test.*

A strike smash inside the red target area was scored with 3 points; blue 2 points and yellow 1 point, whereas strike smash outside the square colored target was scored with zero points.

### *2.4. Core Stability Training Protocol*

The current study was conducted after one month after the preparation phase of the season between Augusts to October in 2016. After the initial testing and before starting the training protocol, all players invited to an instruction special session one week before the study, this instruction session aimed at clearing the core stability training protocol for participants and to explaining how they perform the exercises correctly.

In general, the subjects performed 3 sessions badminton training per week for ~90 - 120 minutes every session; the (CSG) group performed the core stability training only 2 sessions per week over a period of 8 weeks and the (CG) didn't participate in any training and performed only their traditional training sessions. Both groups were involved in the same badminton training programme and the (CSG) group after their warm-up performed the core training exercises which recommended by previous studies [15, 32, 33], with loads, sets, repetitions and rest period considerations of [8, 11, 14, 17, 33]. The (CG) group post-testing session taken after the 8 weeks interval from the pre-testing session.

The core stability training programme of (CSG) group consisted of three progressive levels of exercises which focusing on the strengthening training of muscle abdominal, low back, and pelvic muscles through a variety of functional positions and different exercises. In addition, the exercises during the training intervention including tasks aimed at improving balance and core stability while maintaining neuromuscular control.

The exercises consisted of trunk flexion and extension at a sit-up position, lateral flexion on right and left sides, and also the rotation on both sides. The exercises organized during the training intervention to use the player's body weight, physioball, medicine ball, and swiss ball. During the training practice, there are some exercises repeated from a week to week and this rapidly increased by the difficulties by tasks which consecutively repeated with adding a movement or replacing the surface type. The core stability exercise programs started on 15th August 2016 and concluded on 10th October 2016 and the detailed exercises illustrated in (Table 2, 3).

***Table 2.*** *Schematic illustration of static core stability exercises during training program.*

| Weeks | ***Static core training exercises*** ***Exercise formation was (Time in secs × sets) with 20 seconds rest between sets and different exercises*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Shoulder Bridge** | **Full Plank** | **Prone Bridge** | **Abdominal Crook** * | **Side Bridge** * | **Supine Bridge** ** | **Diagonal Crunch** ** | **Pitcher Squat** *** | **Back Bridge** *** |
| Week 1 | 25 × 2 | 20 × 2 | 20 × 2 | 15 × 2 | 20 × 2 | 25 × 2 | 15 × 2 | 20 × 2 | 20 × 2 |
| Week 2 | 30 × 2 | 25 × 2 | 20 × 2 | 20 × 2 | 25 × 2 | 20 × 2 | 20 × 2 | 20 × 2 | 25 × 2 |
| Week 3 | 30 × 2 | 25 × 2 | 30 × 2 | 25 × 2 | 30 × 2 | 30 × 2 | 25 × 2 | 30 × 2 | 25 × 2 |
| Week 4 | 45 × 2 | 35 × 2 | 25 × 2 | 30 × 2 | 25 × 2 | 40 × 2 | 30 × 2 | 25 × 2 | 35 × 2 |
| Week 5 | 35 × 2 | 35 × 2 | 35 × 2 | 35 × 2 | 25 × 2 | 30 × 2 | 25 × 2 | 35 × 2 | 35 × 2 |
| Week 6 | 35 × 2 | 45 × 2 | 35 × 2 | 45 × 2 | 35 × 2 | 40 × 2 | 35 × 2 | 35 × 2 | 45 × 2 |
| Week 7 | 40 × 2 | 40 × 2 | 45 × 2 | 30 × 2 | 40 × 2 | 30 × 2 | 30 × 2 | 45 × 2 | 40 × 2 |
| Week 8 | 40 × 2 | 45 × 2 | 40 × 2 | 40 × 2 | 35 × 2 | 40 × 2 | 40 × 2 | 40 × 2 | 45 × 2 |

*Note:* * = each side, ** = on physioball, *** = with swiss ball

***Table 3.*** *Schematic illustration of dynamic core stability exercises during training program.*

| Weeks | ***Dynamic core training exercises*** ***Exercise formation was (Repetitions × sets) with 10 seconds rest between sets and different exercises*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Hip Crossover** | **Multi Directions Lung** | **Reverse Crunch** | **Jack Knife** * | **Knee Drive** * | **Hip Thrust** ** | **Knee Tucks** ** | **Russian Twist** *** | **Crunch Ball Hold** *** |
| Week 1 | 8 × 2 | 20 × 2 | 15 × 2 | 8 × 2 | 15 × 2 | 20 × 2 | 12 × 2 | 8 × 2 | 8 × 2 |
| Week 2 | 10 × 2 | 25 × 2 | 20 × 2 | 10 × 2 | 20 × 2 | 25 × 2 | 10 × 2 | 10 × 2 | 10 × 2 |
| Week 3 | 10 × 2 | 25 × 2 | 20 × 2 | 12 × 2 | 20 × 2 | 20 × 2 | 12 × 2 | 8 × 2 | 8 × 2 |
| Week 4 | 12 × 2 | 35 × 2 | 30 × 2 | 12 × 2 | 30 × 2 | 35 × 2 | 16 × 2 | 12 × 2 | 12 × 2 |
| Week 5 | 12 × 2 | 35 × 2 | 25 × 2 | 8 × 2 | 35 × 2 | 35 × 2 | 16 × 2 | 12 × 2 | 12 × 2 |
| Week 6 | 8 × 2 | 45 × 2 | 35 × 2 | 10 × 2 | 20 × 2 | 45 × 2 | 20 × 2 | 10 × 2 | 10 × 2 |
| Week 7 | 10 × 2 | 40 × 2 | 30 × 2 | 12 × 2 | 35 × 2 | 40 × 2 | 25 × 2 | 12 × 2 | 15 × 2 |
| Week 8 | 12 × 2 | 45 × 2 | 40 × 2 | 16 × 2 | 40 × 2 | 45 × 2 | 20 × 2 | 16 × 2 | 20 × 2 |

*Note:* * = each side, ** = on physioball, *** = with medicine ball

*Statistical Analysis*

All measurements data are presented as a mean ± SD and were normally distributed by non-parametric (Kolmogorov - Smirnov) test. An independent sample t-test was executed for examining any significant differences in dynamic balance and strike velocity and accuracy smash performance between experimental and control groups. The significant difference between pre-test and post-test were compared with Paired-sample t-test within each group. Statistical significance was accepted at an alpha level of p-value ≤ 0.05 using (SPSS Inc., Chicago, IL) software version 17.0 for Windows.

# 3. Results

Compared mean values in all measurements between pre and post-test for training group (CSG) and control group (CG) were presented in the following three tables below.

***Table 4.*** *Comparison means, standard deviation and P-value of core stability tests between experimental and control groups and within groups.*

| **Positions** | **CSG (*n* = 10)** | | **CG (*n* = 10)** | | ***(p-value)*** |
|---|---|---|---|---|---|
| | **Pre** | **Post** | **Pre** | **Post** | |
| Ventral (sec) | 120.10 ± 26.09 | 151.20 ± 22.63* | 123.50 ± 29.86 | 126.40 ± 24.86 | 0.03** |
| Lateral - L (sec) | 58.10 ± 11.97 | 70.90 ± 12.81* | 56.30 ± 12.86 | 57.10 ± 14.11 | 0.03** |
| Lateral - R (sec) | 55.60 ± 13.60 | 74.10 ± 14.07* | 54.90 ± 11.13 | 56.40 ± 10.65 | 0.01** |
| Dorsal (sec) | 83.70 ± 14.84 | 102.20 ± 10.48* | 82.30 ± 15.49 | 85.10 ± 10.19 | 0.00** |

*Notes:* CSG = training group, CG = control group, Sec = seconds, Pre = pre-test, Post = post-test, L = left, R = right, * Significant difference from pre-test ($p < 0.05$)
** Significant difference from control group ($p < 0.05$).

The results of core stability tests in four positions in (Table. 4) showed a significant difference between pre and post tests for CSG group in all core test positions; ventral ($P = 0.04$), lateral left ($P = 0.02$), lateral right ($P = 0.02$) and dorsal ($P = 0.00$), however no significant differences showed for CG group ($p > 0.05$) in all core test positions. The independent t-test results showed a significant difference between CSG and CG groups in all core test positions ($p < 0.05$).

***Table 5.*** *Comparison means, standard deviation and P-value of Star Excursion Balance Test (SEBT) between experimental and control groups and within groups.*

| **Directions** | **CSG (*n* = 10)** | | **CG (*n* = 10)** | | ***(p-value)*** |
|---|---|---|---|---|---|
| | **Pre** | **Post** | **Pre** | **Post** | |
| Anterior (%) | 81.90 ± 5.26 | 87.30 ± 6.43* | 80.50 ± 6.49 | 81.80 ± 4.42 | 0.04** |
| Posterolateral (%) | 89.20 ± 8.82 | 98.40 ± 6.31* | 90.30 ± 8.93 | 91.60 ± 6.06 | 0.02** |
| Posteromedial (%) | 85.90 ± 8.67 | 93.80 ± 7.52* | 84.10 ± 8.90 | 85.70 ± 8.86 | 0.04** |

***Notes:*** CSG = training group, CG = control group,% = ratio of total reaching length / leg length, Pre = pre-test, Post = post-test, L = left, R = right, * Significant difference from pre-test ($p < 0.05$), ** Significant difference from control group ($p < 0.05$).

The results of Star Excursion Balance Test (SEBT) in (Table. 5) showed a significant difference between pre and post tests for CSG group in all performed directions of balance test; Anterior ($P = 0.02$), Posterolateral ($P = 0.00$) and Posteromedial ($P = 0.00$), however no significant differences observed for CG group ($p > 0.05$) in all test directions. The comparison between CSG and CG groups using independent t-test showed a significant difference in all balance test directions ($p < 0.05$).

***Table 6.*** *Comparison means, standard deviation and P-value of smash stroke performance test between experimental and control groups and within groups.*

| Variables | CSG ($n$ = 10) | | CG ($n$ = 10) | | *(p-value)* |
|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | |
| Accuracy (P) | 16.60 ± 2.07 | 21.30 ± 2.58* | 15.20 ± 2.74 | 17.10 ± 3.45 | 0.01** |
| Smash Velocity (km.h) | 117.10 ± 16.46 | 133.80 ± 11.92* | 116.30 ± 15.57 | 119.50 ± 12.43 | 0.02** |

*Notes:* CSG = training group, CG = control group, P = points, km.h = kilometer per hour, Pre = pre-test, Post = post-test, L = left, R = right, * Significant difference from pre-test ($p < 0.05$),
** Significant difference from control group (p < 0.05).

There were significant differences showed in (Table. 6) between pre and post tests for smash stroke accuracy and velocity in CSG group (P = 0.00) and (P = 0.00), respectively, however no difference observed between both tests in CG group (p > 0.05). The smash performance test results showed significantly differ between CSG and CG groups in accuracy and velocity variables using independent t-test (p < 0.05).

# 4. Discussion

The aim of current study was to investigate the effect of core stability training over 8 weeks to increase the core muscle endurance ability for U 19 badminton players, and to examine its influence on dynamic balance and the performance of forehand smash stroke. In general, the results showed that 8 weeks of core stability training can elicit significant improvements in dynamic balance, smashing velocity and accuracy.

The results showed that, eight weeks of core stability training for CSG group increases the core muscle endurance ability with an improvements percent of 26%, 22%, 33% and 22% in core test positions ventral, lateral left, lateral right and dorsal, respectively. However, no significant increase in core muscle endurance observed for CG group. The outcome results of core endurance scores consisted with study by [34] who confirmed that core training two times per week for six weeks as relatively the period of training in current study provided an improvements in trunk flexor, extensor endurance and right lateral endurance.

Dynamic balance (SBET) test results of current study showed a significant improvement in total reached distance for CSG group; anterior ~7%, posterolateral ~10% and posteromedial ~9%, whereas there were no significant change in CG group after their traditional training.

The core stability training exercises during the training intervention were varied and included special exercises for hamstring muscles whether exercises static or dynamic to development the strength of pelvic and back muscles. In addition, core exercises such as knee drive and multidirectional lunges may affect total reached distance of players when performed the dynamic balance test and stand on a single limb and also may have a direct influence on hamstring strength values of badminton players.

The dynamic balance test findings are consisted with previous studies, which investigated the effects of core training on dynamic balance for athletes. [35] Found that 8 weeks core stability training occurred increase of 103% in dynamic balance (SEBT) test results and [36] found significant increases in torso strength, hip strength and balance after 8 weeks training included abdominal and hip strengthening. [37] Suggested that 8 weeks core stability training includes static and dynamic exercises like current study increased core endurance test times when compared to the control group of elite junior players.

[15] found that a 6 weeks core strength training resulted an improvements at the total reached distance of the dynamic balance (SEBT) test (relatively anterior 8%, posterolateral 5% and posteromedial 5%) in adolescent badminton players, who participated in training programme consisted of 3 levels with 6 core exercises for three sessions per week. In this study, the core endurance test scores of adolescent badminton players showed highly significant at post-training when compared to the pre-training in CGG group.

In tennis sport as a most popular racket sport, [32] found that 5 weeks core stabilization training improved the total reached distances of dynamic balance test in tennis players when compared to the control group after the training programme which focused on strengthening the core muscles while maintaining neuromuscular control as the current study core exercises in the training programme.

The previous studies which have used various core stability exercises during different training programmes and with number of about 2 to 3 sessions per week suggested that core muscles stabilizing the lumber spine which provides an increase in total scored distance of (SEBT) test and supporting the lower limb movements. In this context, core stability training exercises are vital for badminton players who need higher hamstring muscular forces which aiming to provide a dynamic support for the movements that required a better knee stabilization to complete a landing-based tasks such as overhead smash stroke in short period time and with stand stable leg to ready for following tasks during the badminton game.

To my knowledge, the current study is the first study which investigated the effects of core stability training on overhead smash stroke performance (smashing velocity and accuracy). The results showed an increase in smashing velocity ~28% and smashing accuracy ~14% after the CSG group completed 8 weeks of core stability training when compared to CG group. A possible explanation for these outcomes is that, the core training programme includes some dynamic exercises with medicine ball and physioball such as crunch ball, Russian twist and hip trust which increase the endurance of core muscles for players to using their lower and upper extremities unilaterally during smashing the shuttlecock in badminton.

Comparisons smash velocity and accuracy results in current study with previous studies it's seem partly difficult because there are not similar studies investigated in badminton sport, however little studies focused on current interesting point research. In tennis sport, [38] examined the effects of 6 weeks training program includes core strength on serve velocity in youth tennis players, their results showed that training group players improved in serve velocity ~5% and accuracy ~11% when compared to control group. The current mean value results of smashing velocity showed relatively similar to previous research analyzing the shuttlecock velocity of smash stroke (43). In addition, in badminton sport, [39] found that 6 weeks core strength training increase the accuracy points in forehand clear ~8% and backhand clear ~14% skills in badminton players when compared to the control group.

Although, overhead smash stroke performance is a complex motion, which depends on several components such as lower body strength, leg power, technique and the proper kinetic chain [12, 23, 40], the core stability training varied movements in current study allows players to perform the exercises at high rhythmus speed compared with traditional strength training which depend on free weights or machines, but with greater force compared to those performed during sport competition [8, 10, 14]. Moreover, it can be explained that the positive smashing velocity and accuracy results by the high coordinative closeness of core stability exercises which were selected based on the nature of badminton sport which characterized by many repetitive striking.

The upper-body and rotational trunk strength are important vital variables for badminton players because both play an important role to drive the body during smashing movement in the final phase of smash skill. In this regard, trunk rotation and core muscles endurance are integral parts of the improvement power and transfer the energy up to the kinetic chain from lower body to upper body extremity transferred [14], this mechanism confirmed by previous studies which reported significant improvements in trunk strength after core stability training [6, 9, 12].

Finally, dynamic balance and core muscle strength related to the smashing movement motion and specially the performance of overhead smash stroke variables such as smashing velocity and accuracy, this have been showed clearly by the applied of 8 weeks training.

## 5. Conclusions

In conclusions, the present results showed that 8 weeks core stability training programme is an effective training method for developing the dynamic balance for U 19 badminton players and elicit significant improvements in the technical functional performance of smashing velocity and accuracy. The current study results highly recommend the uses of core stability static and dynamic exercises training combined with regular badminton striking in the court and organized as circuit training, which could be applied as a part of a shoulder injury prevention warm-up for badminton players. Because smashing performance is one of the most relevant key successes to score critical points in badminton matches, the core stability training based on badminton-specific movement patterns conducted 2 times per week over 6 weeks as a minimum period, which may be helpful in improving functional performance levels of badminton players. In addition, core stability training can be considered as an appropriate standard warm-up and training method for developing the strength. Indeed, highly considerable thing that badminton coaches establishing the core training exercises during the in-season competitive phases.

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