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Awareness and Association of Dynamic Stability and Core Muscle Strength in Professional Padel Players – A Cross-sectional Study

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Abstract **Objective:** The aim of this study was to investigate gender differences while comparing dynamic stability and core strength and to identify relations among professional padel players. **Methods:** This cross-sectional study was planned in Jeddah city of Saudi Arabia. A total of 30 players was recruited out of which 15 were males and 15 were females. Each participant was informed about the nature and importance of studying prior data before data collection and an informed consent was also obtained. The data was collected from six padel centers as per plan located across the city using physical examination form divided into three sections: Demographic details, Plank test time and SEBT (star excursion balance test). **Results:** Findings of this study suggested that despite SEBT mean reach distance score (males>females) was comparable based on gender, the difference remained non-significant (p>0.05). Plank test time between males and females were also found to be non-significant. Correlation analysis showed weak to moderate positive relation between plank time and SEBT for both dominant and non-dominant leg side, however, only significance was found for anterior reach direction (r = 0.407, p-value = 0.026). **Conclusion:** The findings of this study showed that dynamic stability and core endurance between male and female players of padel sport does not show any significant reach differences attributed to similar levels of training adaptations. On analyzing the association between core strength and reach distance, it was found that the anterior direction movements were more stabilized than others in both the genders suggesting the importance of forward leaning position more prominent in padel sport. This study also reinforces the importance of core strength in maintaining dynamic stability related to this sport.

Key Words Dynamic stability, muscle strength, padel, sex characteristics, sports

INTRODUCTION

Padel sport has become one of the fastest growing and most popular sports around the world [1]. It was estimated that more than 25 million active padel players are present considering both professional as well as non-professional (federative licensed players 65% male and 35% female) in different parts of the world (International Padel Association, 2023). Padel is a hybrid sport that combine elements of both tennis and squash often played as doubles. Although rules of game does not specifically differ based on gender unlike lacrosse, however performance during game may show some variability attributed to either anatomical structure of males and females, different body control mechanisms, or sufficient volume of strength, agility and speed [2,3]. This sport activity involves rapid movement of players in multiple directions [4], thus training is very important to maintain dynamic balance and coordination during game and transferring motion to terminal segments of lower body peripheries like foot kinetics [5,6].

Being a racquet sport with periods of intense and light play, this game involves sudden acceleration or deceleration movements like backward, forward, lateral and truck rotation on pelvis (wider pelvis in females than males may also be related to angulation of core muscle attachments in them) which benefits anticipation during ball's trajectory [2]. Thus, stable and coordinated movement during play allow the players to keep body's Center of Gravity (COG) aligned [7]. Core muscles strength (both local and global) like rectus abdominus, obliques, traverse abdominis, erector spine, multifidus [3]; remains key in fulfilling this requirement and

allows force generation due to high intensity motion [8]. Therefore, optimum training module for both male and female players become very important factor in preventing sports injury during game and in practice sessions [8,9].

As the game requires uninterrupted, smooth, coordinated and stable transfer of energy from upper extremity, core to lower extremities, therefore factors like muscle mass (both male and female), anthropometric parameter like BMI, age, sex etc., along with core strength may also affect these indicators [3,10]. Furthermore, when we consider padel sport through gender perspective, it has been documented that differences in balance and core strength arise as a result of combination of a different biological, biomechanical, hormonal and neuromuscular factor. According to study, it was concluded that gender does show stringer correlation between core stability and athletic performance. However, this observation was not clearly documented in case of padel players in particular, although evidences from different geographical regions indicates it may have been associated with athletic performance of the players. Hence, considering gender, it becomes important to understand how this affects dynamic stability and core strength in padel players.

Existing literatures have provided enough evidences regarding comparison between male and female players across different sports such as tennis, football, however, clarity with respect to padel players was found to be scant. Studies by Pradas *et al.* [11] compared fitness profiles of padel players between male and female but has not evaluated the functional balance test and dynamic core activation during actual game play. Considering this, authors of this study has decided to explore similar correlation among male and female players using neuro-muscular tool to understand the dichotomy between core endurance and functional balance among padel players. Furthermore, this correlation has not been explored in Jeddah city, which has recently gained a lot of popularity in this region. Therefore, the objective of this study was to investigate and assess correlation between core muscle strength (using plank test) and how it contributes to the dynamic stability of posture (using SEBT) among padel players in Jeddah Saudi Arabia.

METHODS

Study Design and Sample Size

A cross-sectional study was planned with total of 30 padel players from six different padel centers in Jeddah, Saudi Arabia. A power analysis was done using G power indicated that sample size of 30 participants would be enough in order to measure the medium effect size (d = 0.50) with 80% power at alpha level of 0.05. All the 30 participants were selected by simple random sampling using random number table. The equal number of males (n = 15) and females (n = 15) were chosen for this study. The method was repeated until number of males and females were equal. Age of recruited players was above 18 years (with an average age of 25.73±4.46 years).

Eligibility Criteria for Recruitment of Participants in Study

Participants included in this study must be healthy adults, with age above 18 years and should have at least six months of padel training experience. Additionally, participants must have had no injuries in the past six months without any history of cardiac problems or neurological disorders. All those individuals who have less than six months of padel training experience and a history of any primary disease like cardiac, musculoskeletal, or neurological issues were excluded from the study.

Outcome Measurement

Following outcomes will be measured by pre-designed physical examination form which consists of three sections:

- Demographic details and leg length measurement for both right-side and left-side, to facilitate standardized reach distances during SEBT. The equation to normalize the standardization of the results is:

$$\text{Normalized reach distance (\%)} = \frac{\text{Reach distance (cm)}}{\text{Stance limb length (LL)}} \times 100$$

Where, Excursion distance: Measured distance of reach (in centimetres), Stance Limb Length (LL): Length of the stance limb (in centimetres), Normalized Reach Distance (%): Reach distance expressed as a percentage of the stance limb length.

This methodology was in accordance with the study conducted by Gribble *et al.* [5] and Alshehre *et al.* [12] which demonstrated the use of normalized SEBT reach distances to identify limb asymmetries in healthy and injured populations. Similarly, Appiah-Dwomoh *et al.* [13] has also used this method for sample size calculation while investigating star excursion balance test in young athletes with back pain.

Core Stability

Participants were explained about the test in detail. The plank test was performed in prone position with both the elbows at 90° with ground and shoulder in flexed position. Trunk was asked to lift above the ground aligning itself with the position of shoulders and feet. Both shoulder and feet were wide apart (Figure 1). The basic plank test has high validity as well as good test-retest reliability. Participants were asked to hold plank position for as long as possible with an intermittent rest of 2 minutes in between all the three attempts. Core strength was tested using the plank hold in the prone position and the average of three attempts was calculated. As previous studies have already demonstrated higher interrater and intra-rater reliability (ICC>0.9) of plank's test in assessing core endurance, hence it has been used in the current study for its proven statistical evidence [14].

Figure 1: Participant of study performing plank test

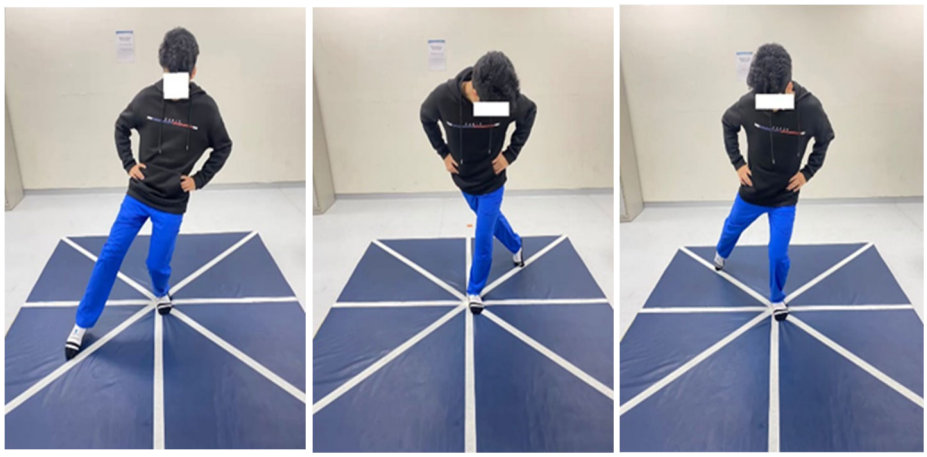

Figure 2: Participant of study performing SEBT

Dynamic Stability

SEBT assessed participants reach distance in eight different directions namely; anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral; measuring dynamic postural stability in all three planes frontal, transverse, sagittal. During the test, participants were asked to stand in the center of the grid. Participant were asked to maintain single leg stance on one leg while reaching as far as possible with the contralateral leg (Figure 2). Reach distance was recorded for nearest 0.5 cm in each direction. Participants completed test in three attempts for each leg and final scores were calculated based on average of these three trials for all the eight directions. SEBT has good construct validity as well as good test-retest reliability. Selection of SEBT test to measure dynamic stability was due to its proven reliability and validity by previous studies. Range for interrater and intra-rater reliability for this test was between 0.81 to 0.96, refarming reproducibility of this test. Also, Hertel *et al.* [15], used this test to identify chronic ankle instability showing SEBT relevance for postural stability evaluation (5,15,16).

Protocol of the Study and Ethical Approval

Following Figure 3 explains the protocol of this study:

Ethical Approval

This study has been approved by Local Research Ethics Committee (LREC) at FoM & KAU, King Abdulaziz University (Reference No. 282-24).

Procedure for Data Collection

Anthropometric measurements were taken initially followed by plank test and SEBT during the visits to all six centers of study and test data was collected under guidance of an expert. Furthermore, to minimize observer bias during data collection procedure, the observers were specifically trained for standardized data collection methods where we also implemented blinding at all stages possible (Figure 4).

Figure 3: Flowchart of protocol of the study

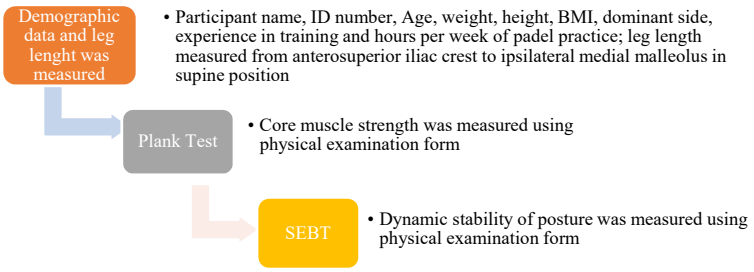

Figure 4: Procedure of the study

Data was collected using physical examination form with three sections:

- Participants information and leg length measurement
- Plank tests results: Time taken to complete each test for three times
- SEBT test parameters using standardized data recoding form of this test

Data Management and Statistical Analysis

Data collection was then managed using MS Excel. This data was then analyzed through Statistical Package for Social Science (SPSS) software version. Demographic characteristics were calculated using descriptive statistics and summarized in form of Mean±standard deviation and range. Study data was assessed for normality using Shapiro-Wilk test (data significant for test). Independent t-test was performed to compare both the genders. Pearson's correlation analysis was performed to investigate relationship between core strength and dynamic postural stability. Value for significance was accepted at $p<0.05$. Furthermore, the findings of this study have been reported based on STROBE Checklist which has been considered standard tool for reporting observational studies [17].

RESULT

Following section is divided into four parts, namely; Participant characteristics, Comparative analysis of dynamic stability and core strength between categories of gender, Relationship between Plank Test and SEBT to assess correlation between dynamic stability and core strength and summary of overall analysis.

Participant Characteristics

A total of 30 participants recruited in the study, out of which 15 were females and 15 were males. Most of the participants were right side dominant (86.7%) compared to left side dominancy (13.3%). Equal number of males and females were recruited ensuring unbiased and fair analysis of outcomes variables (Table 1, 2).

From Figure 5, it can be observed that leg length measurements were equal in both the legs. According to BMI, there were few participants in overweight category however, mean BMI identified to be 21.53 reinforces that most of them were healthy. Maximum weight identified was 95 kg which may have altered the outcome of BMI in particular.

Comparative Analysis of Dynamic Stability and Core Strength Between the Genders

This overall analysis highlights that with a sample size of 30 padel players (both male and female), dynamic stability based on reach distance remains were relatively similar, although males tend to show slightly better stability dynamics than females. The overall difference however, remained non-significant ($p>0.05$).

Comparative Analysis Based on SEBT Between the Two Genders to Understand Variation in Dynamic Stability

Recruited participants were asked to undertake distance reach test for both dominant and non-dominant leg sides in different directions. Test was performed using SEBT tool and analyzed using SPSS software. Findings of the tests were summarized in Table 3 and in form of box plots in Figure 2. Overall results indicated that although males have higher reach distance (in both dominant and non-dominant leg

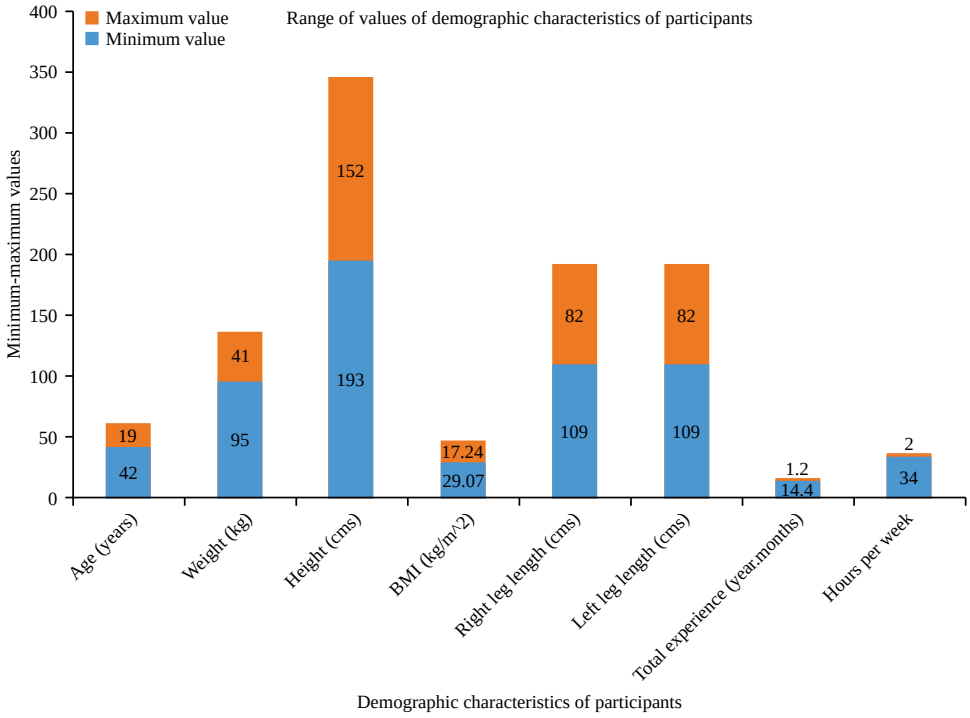

Figure 5: Range of minimum and maximum values of demographic characteristics of participants

Table 1: Distribution of participants by sex and dominant side

Variable	Category	Frequency	Percent
Sex	Female	15	50.0
	Male	15	50.0
Dominant side	Left	4	13.3
	Right	26	86.7

Table 2: Characteristics of study participants

Variable	Mean	Std. Deviation
Age (years)	25.73	4.46
Weight (kg)	62.57	13.45
Height (cm)	168.23	10.21
BMI (kg/m^2)	21.93	3.23
RT leg length (cm)	92.20	6.02
LF leg length (cm)	92.20	5.94
Years and months of experience	4.14	3.14
Hours per week	7.63	6.51

sides) in all eight directions compared to females, however, results were found to be statistically insignificant (p>0.05).

Anteromedial direction shows reach distance for both males (72.31±8.58) and females (72.06±5.59) to be nearly same, with only marginal difference of 0.25 units between them (males>females). Also, when mean reach distance was compared between them, analysis showed that for dominant leg, it was maximum in posterolateral direction in males (86.54±9.69) and posterior direction in females (83.89±9.05). When non-dominant leg side was compared, it was found to be maximum posterior direction (85.69±9.21) in males and posterolateral direction (82.51±10.60) in females. However, mean difference (ranged between -0.249 to -5.904) was found to be statistically non-significant (p>0.05; ranged between 0.066 to 0.926) in all the eight directions among both the genders for both dominant and non-dominant leg sides.

Comparison Based on Plank Tests Between the Two Genders

When comparison was performed based on plank test time between male and female participants, it was observed that plank time was slightly more for males (115.53 secs) than that of females (109.13 secs). However, mean difference (-6.400) between them, for all the directions remained statistically non-significant (p-value = 0.772). This reflects the influence of training for core strengthening more profoundly over differences in gender.

Following Figure 6, represents overall comparison between the two genders for both dominant and non-dominant leg side through box plots. On comparing males and females, median scores variability in between the categories was insignificant. Outliners in the box plot highlights that, though variability in SEBT scores exists in few directions like medial and posteromedial, it can be attributed to wider interquartile range (IQR). Plot areas under plank tests shows that females have slightly larger spread pointing out the variability as observed. Overall analysis show consistency in performance by both the gender category in dynamic stability and core strength. Therefore, we accept null hypothesis which suggest no significant association between categories of gender in core muscle strength and or dynamic stability among padel players in Jeddah, Saudi Arabia.

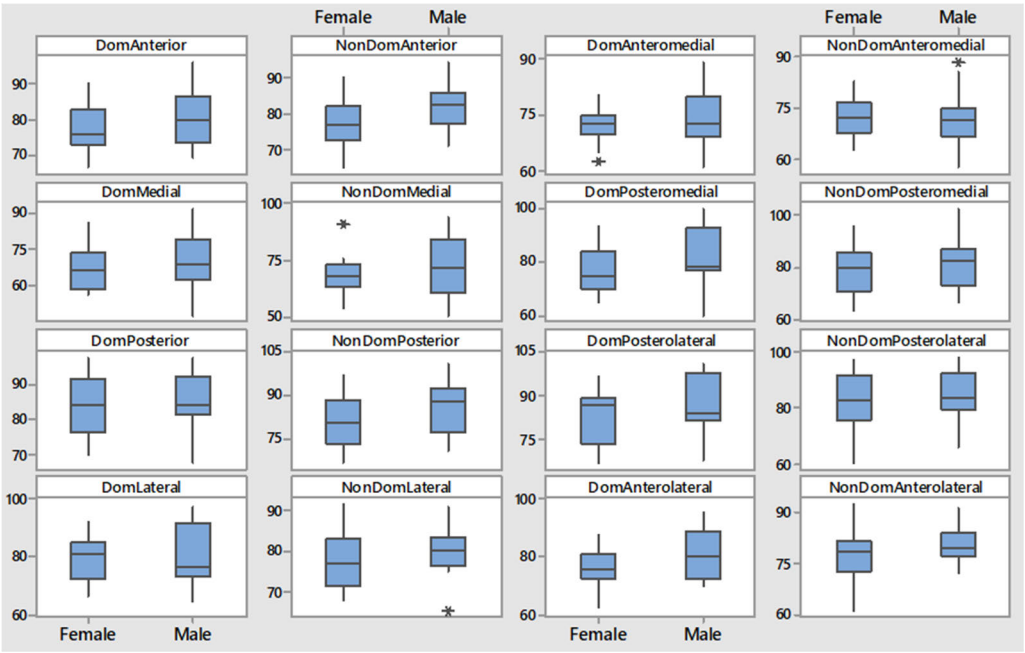

Figure 6: Difference between males and females in SEBT and plank test

Table 3: Difference between males and females in SEBT and plank test

Variable		Male	Female	Mean difference	p-value
Anterior	Dominant	80.35±8.50	76.90±6.26	-3.448	0.216
	Non-Dominant	81.63±6.88	76.76±7.05	-4.870	0.066
Anteromedial	Dominant	74.23±7.89	72.02±5.05	-2.214	0.368
	Non-Dominant	72.31±8.58	72.06±5.59	-0.249	0.926
Medial	Dominant	70.51±12.38	67.62±8.58	-2.892	0.463
	Non-Dominant	71.64±13.03	68.59±8.91	-3.053	0.460
Posteromedial	Dominant	81.94±11.79	76.04±8.66	-5.904	0.129
	Non-Dominant	81.41±9.95	78.13±9.07	-3.278	0.354
Posterior	Dominant	84.72±8.08	83.89±9.05	-0.827	0.794
	Non-Dominant	85.69±9.21	81.15±8.93	-4.536	0.182
Posterolateral	Dominant	86.54±9.69	82.84±9.35	-3.696	0.297
	Non-Dominant	84.71±8.45	82.51±10.60	-2.205	0.534
Lateral	Dominant	80.83±10.25	79.69±8.10	-1.143	0.737
	Non-Dominant	80.19±6.34	77.74±7.27	-2.452	0.334
Anterolateral	Dominant	81.66±8.91	76.39±7.08	-5.272	0.084
	Non-Dominant	80.79±5.15	77.49±7.83	-3.297	0.184
Plank Test time (sec)		115.53±53.21	109.13±65.92	-6.400	0.772

Relationship Between Plank Test and SEBT among Padel Players Based Dominant and Non-dominant Side

Table 4, reflects the nature and type of relationship between dominant and non-dominant leg sides in different direction in padel players. Overall findings show "anterior reach" of dominant leg side to be statistically significant at 0.026 (p-value), suggesting anterior reach on dominant side performs better core strength association with anterior reach direction in participants on dominant leg side.

Dominant Side Leg Category

It was observed from Table 4, that there exists weak to moderate positive correlation (coefficient correlation (r) ranges between 0.106 to 0.338) between plank test and SEBT across different directions with no statistical significance (p-value ranged between 0.067 to 0.833) except anterior reach. Nature of relationship between the two test variables for anterior reach showed significance at p = 0.026, suggesting its importance in padel players. Analysis of result indicates that in case of posterolateral and anterolateral reach, correlation between plank test and SEBT was moderate positive at (r) = 0.358 and 0.338, respectively, however, statistical significance despite being closer to the set value of p<0.05, largely remained non-significant (p = 0.052 and 0.067, respectively).

Non-Dominant Side Leg Category

On analyzing both the categories of leg sides, plank test and SEBT showed existence of very weak to very weak positive correlation (r = 0.018 to 0.290) at p-value

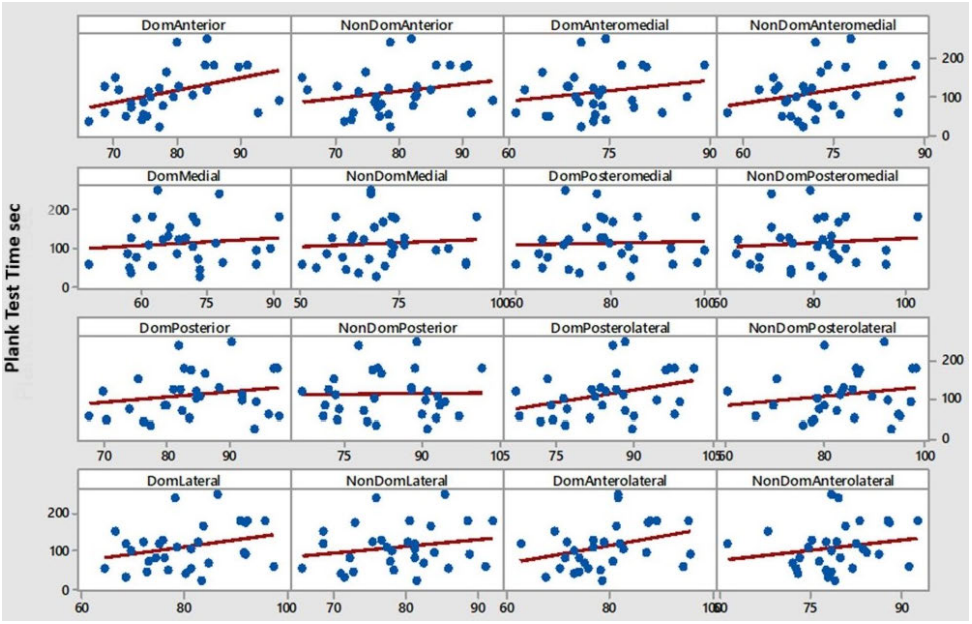

Figure 7: Correlation plot between plank test and SEBT

Table 4: Correlation between plank test and SEBT

Variable		Correlation (r)	p-value
Anterior	Dominant	0.407	0.026
	Non-Dominant	0.229	0.223
Anteromedial	Dominant	0.198	0.294
	Non-Dominant	0.290	0.120
Medial	Dominant	0.106	0.576
	Non-Dominant	0.078	0.683
Posteromedial	Dominant	0.040	0.833
	Non-Dominant	0.095	0.618
Posterior	Dominant	0.202	0.283
	Non-Dominant	0.018	0.923
Posterolateral	Dominant	0.358	0.052
	Non-Dominant	0.184	0.331
Lateral	Dominant	0.301	0.107
	Non-Dominant	0.194	0.305
Anterolateral	Dominant	0.338	0.067
	Non-Dominant	0.206	0.275

r: Pearson's correlation coefficient, Significant at $p<0.05$

>0.05, across variable categories in all the eight directions. Thus, reinforcing non-significance between them.

Figure 7, summarizes nature of correlation between plank test and SEBT graphically using scatter plots. It demonstrates linear relationship between the two variables with a slight positive slope indicating nature of relationship between them. It can be observed that with increase in core strength, results in small improvement in dynamic stability. On comparing performance direction wise, it was observed that point clusters were close in case of anterior, anterolateral, posterior and posterolateral, directions indicate moderate positive correlation between variables in dominant and non-dominant side leg category. While for posteromedial, anteromedial and medial directions cluster dots are largely scattered across plot area, indicating weak to very weak positive correlations among variables. Therefore, we accept null hypothesis which suggest no significant association between plank test and SEBT among padel players in Jeddah, Saudi Arabia.

DISCUSSION

This study investigated differences between male and female participants assess dynamic stability and core strength association using SEBT and plank test respectively. The overall findings of this study reflects that there was marginal difference between scores of males and females during SEBT where males outperformed females in all the directions (however, remained insignificant) and weak to moderate positive correlation was found among between them

(although not significant). This can be attributed to the fact that influence of gender on stability and core strength was marginal due to consistent training of players [11].

The assessment of dynamic stability was performed using SEBT tool which is considered to be useful in determining dynamic stability thereby preventing occurrence of injury and damage to the players [18]. For assessing core strength as such clear indication for any particular tool was not found however, plank tests are widely used methods to examine muscle strength [14,19,20]. Plank enables isometric contraction of core muscles leading to strengthening of even respiratory and abdominal muscles thereby improving endurance in core [20,21]. Thus, sports training with planks also ensures improvement in dynamic stability and efficiency in performance during game [22,23].

The current study considered gender-based comparison for both dominant and non-dominant leg sides showed that difference between male and females in SEBT mean reach scores (however non-significant). It was found that between the two genders for dominant and non-dominant limbs (for all directions), males have higher reach than females. This can be due to anthropometric differences between males and females [24], muscle mass [3], or anatomical structure of body [18]. This study result was supported by Gribble *et al.* [5] and Ahmed *et al.* [25]. Similar results were found on comparing plank time between male and female suggesting comparable capacities of both due to efficient training enhancing athletic agility resulting in superimposed gender based physiological differences [1,26,27]. The dominant and non-dominant leg sides SBET scores also reflected posterior and posterolateral position in male and female. For males, it was posterolateral direction with dominant leg and in females, it was posterior direction with dominant leg having highest reaches during the test. The results indicated reversal reach distance when compared based on non-dominant leg sides, where males have higher reach in posterior direction compared to female who showed better reach for posterolateral direction. This could be attributed to the positions more prominent in padel players like forward lunging or backward lunging [2,4,9,26]. Furthermore, findings mentioned by Gribble and Hertel [28] also supports this observation suggesting that males outperform female in posterolateral direction compared to females [5,16,28]. Similarly, study by Plisky *et al.* [29], Munro and Herrington [30], Zech *et al.* [31] also concluded that due to differences in lower limb strength with better hip mobility and trunk stabilization, males tend to favour posterolateral direction (29-31). These studies also highlighted that in case of females, females have wider pelvic structures and greater Q-angle naturally favors posterior movement. Also, study such as Gribble & Hertel [28] also documented that there have been differences in neuromuscular controlling strategies among male and female which led them adept certain specific movements during the play. For males, muscles such as gluteus medius, gluteus maximus and vastus lateralis, strengthens with intensive training periods suggesting different muscle mass distribution than females (possess greater hamstring flexibility and endurance supporting more controlled and less rotational movements) [28].

In addition to this, analysis from this study also indicated that minimum reach distance was observed in both the genders was medial direction. This can be attributed to minimal use of this position while playing padel [4,11,32]. Studies have also shown similar patterns while analyzing other types of sports like basketball, volleyball etc. [6,33-35]. This indicates effects of proper training modules in improving agility and performance in field particularly in those sports where significance of quick directional changes is very important.

Relationship between dynamic stability and core strength shows pronounced significant correlation only in "anterior reach" direction (although positive correlation found in all direction however insignificant) which may be associated with "forward lunging" position during the play. All the other directional movements did not establish association with core strength, thereby suggesting that only certain directions relevant to that sport have added advantage of core strengthening [5,33]. This result was supported by Silver [36] highlighting importance of core strength in neuromuscular control, while quick accelerative or decelerative movements of body [37,38]. Anteriorly leaning forward positions typically require core muscle strength to support stable trunk movement over pelvis while maintaining body's Center of Gravity (COG) [33,39]. This enables in counterbalancing sagittal plane movement without compromising stable posture [26]. However, our results have shown that it is not true for many other directions. Sports with specific movements, like padel, tennis or badminton, undertakes exhaustive training can also be the reason for variability in considered directions [25,40]. Moreover, many studies have evaluated association of core strength with dynamic stability in different sports, however, study by Firouzjah *et al.* [10], points out positive effects of core stability training on torque of trunk's flexors and extensors, enabling efficient control in postural movement in basketball players. Overall, the existing literature on padel sport does not clearly evaluate the correlation between the two variables and hence authors of this study emphasize on conducting more comprehensive studies with larger sample size to generalize the findings. This result was also emphasized by other studies [8,41-43].

CONCLUSION

Padel sport, today, is played in many parts of the world, therefore making it at an important area of research. This study demonstrated gender-based comparison in maintaining dynamic stability and core strength in the padel players. Using neuromuscular tests, this study exclusively provides insights from perspective of gender in padel sport. The findings of this study also suggests that padel sport is more susceptible to non-contact musculoskeletal injuries due to

differences in movement and core strengths among players, however, current studies largely fail to address the sport-specific injury. Thus, authors of this review strongly emphasize on evaluating nature and pattern of non-contact musculoskeletal injuries in addition to other gender specific researches on larger sample size to further fill the knowledge gap associated with this. Moreover, this information in future may also assist stakeholders in setting the effective training modules to improve the performance.

Limitations of the Study

This study was conducted on smaller sample size limited to only one geographical location; thus, the generalizability of the findings has been limited. As this sport is increasingly becoming popular, more comprehensive study could be planned in future. Although review studies were there, authors identified substantial lack of interventional researches. Therefore, more focus can be given to these study designs to get better insights related to padel sports.

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