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COMPARISON OF TENNIS BALL HITTING POWER FROM CLOSED AND SEMI-OPEN STANCES[1]

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Abstract: The study aimed to determine the differences in forehand stroke power between closed and semi-open stances in tennis.
The strokes of 8 retired performance tennis players were analyzed, comprising 4 women (20.25±3.40 years, 166.50±4.49 cm, 66±14.57 kg) and 4 men (21.50±2.89 years, 178.38±8.44 cm, 79.45±17.97 kg). In addition to ball speed, the explosive power of the lower limbs (Squat Jump, Countermovement Jump, Countermovement Jump with Free Arms), upper limbs (medicine ball throw) and wrist flexor strength were measured.
The data analysis revealed an insignificant difference between the two hitting stances, with the ball achieving similar speeds ($t=0.6624$, $df=7$, $p=0.529$). The ball displacement from the closed stance showed insignificant correlations with the analyzed anthropometric and strength parameters. In contrast, the semi-open stance showed significant correlations with the results of the three forms of the medicine ball throw (overhead throw – $r=0.85$; forehand – $r=0.78$; backhand – $r=0.78$).
Striking the ball from both semi-open and closed stances results in similar ball speeds. The speed achieved from a semi-open stance is associated with the explosive strength of the upper and lower body.

Keywords: closed stance, semi-open stance, ball speed, forehand

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Introduction

Achieving significant ball speed during groundstrokes associated with an important factor in tennis (Lambrich & Muehlbauer, 2024). The open stance forehand has been shown to be more traumatic to knee health in tennis than the neutral stance forehand (Martin, et al., 2021). The forehand is second in importance to the serve. The improvement is based on key factors such as the importance of axial rotation of the pelvis, trunk, horizontal adduction of the shoulder and internal rotation (Reid, et al., 2013).

Some specialists have compared knee kinematics and kinetics in tennis players during the forehand stroke in neutral attacking, open attacking and open defensive positions. In order to determine the position that induces the greatest loads on the knee and what are the uses brought to it, they used the calculations between the angles of flexion-extension, abduction-adduction, external-internal rotation, intersegmental forces and torques of the right knee. The defensive open position poses a higher risk in terms of potential knee injuries (Martin, et al., 2021).

Although open (i.e. hip parallel to baseline) is predominantly used (60-70%) (Elliott, et al., 2019; Reid, et al., 2013), researchers consider biomechanics advantages compared to the square position (i.e. hip perpendicular to baseline). Given the open stance, the researchers found no significant differences in racket control, vertical racket trajectory, and trunk angular velocity at impact between, compared to the square stance (Lambrich & Muehl-bauer, 2024). For example, the distribution of positions used by Federer seems relatively stable on grass and clay courts, while the player Falla uses the forehand from an open position less often (~50%), but almost 3.5 times more shots from a square stance on grass than on clay courts (Reid, et al., 2013).

Lambrich & Muehlbauer (2024) found through their research that higher values were recorded from the open stance, although values adjusted for ball speed after impact in the square stance longline forehand groundstrokes (topspin) indicate different advantages in both styles, suggesting their specific application to the situation.

Some have researched the role of knee positioning in the closed forehand. Initial knee placement was found to influence racket speed. Effects on racket movement are minimal, however there are some indirect biomechanical effects on movement such as movement of the body's center of mass, stress on the knee joints (Nesbit, et al., 2008).

The techniques used in the tennis forehand have changed drastically in the last 10 years. Today's players rarely use the traditional forehand. Instead, most top amateur and profes-sional players use the modern topspin forehand. Changes in forehand technique were attributed to new racket models. Modern rackets are larger, lighter and stiffer, allowing players to hit the ball with more power and control. These changes in forehand technique influenced grip type (east, semi-west, or west), footwork (open/close), racquet back loop (straight or loop), and forward swing (single vs. multiple) of today's tennis players (Beha-monde, 2016).

Some have used sensors, placed on the racket handle at the level of the hypothenar eminence and the base of the index finger, to measure the forces during the forehand stroke. All subjects showed an increase in grip forces at the hypothenar sensor before impact. Although pre-impact forces showed a consistent pattern, impact forces were variable, ranging from 4 to 309 N (Behamonde, 2016).

Trunk rotation has been shown to be significantly correlated with racquet speed, regardless of the type of stance used or skill level (professional or intermediate), trunk rotation not only contributes to racquet speed (10% of final racquet speed), but is used and in prestretching the shoulder muscles allowing them to produce more power (Behamonde, 2016).

Schönborn R. (2011) presents the closed position as ineffective due to the limitation of kinetic muscle potential. The opposite of this situation is given by the open position of the legs which allows the upper part of the trunk a complex backward rotation, followed by the discharge of the accumulated kinetic energy forward.

Rigozzi et al. (2023) developed a wearable device to measure injury risk factors such as grip strength, forearm muscle activity, and vibration data. These are directly correlated to the degree of tendinitis tennis players suffer from hitting technique.

The forehand technique in the open position is harmful to the body, analyzing the strokes of both professional and intermediate players. The data supported that the open position technique creates more loading throughout the upper extremity. Upper extremity peak torques represent loads that could contribute to strength imbalances and injuries (Bahamonde & Knudson, 2003).

Parpa et al. (2022) focused on demonstrating the correlation between physical performance, anthropometric characteristics and kick speed among young players. The athletes were tested anthropometrically and from the point of view of physical training, following them to use the forehand, backhand and service shots on the tennis court. Forehand stroke strength was directly correlated with height and grip strength, backhand stroke strength was correlated with running speed and grip strength, and serve strength was correlated with height, running speed and grip strength, these characteristics corresponding to men. Significant female-specific correlations were found only between service stroke force and their weight.

Methods

The research included 8 tennis players with a minimum of 3 years of experience, including 4 girls (20.25 ± 3.40 years) and 4 boys (21.50 ± 2.89 years, *Table 3*).

In the ball speed test, the boys used their own racquets with head sizes between 98 in² and 100 in² and weighing between 310 and 325 grams. The girls used racquets weighing between 290 grams and 325 grams, and the head size was between 98 in² and 100 in². The weight noted is that specified by the manufacturer, i.e. without connection. The rockets weighed 325 grams, their base weight was 305 grams, and the lead strip weighed 20 grams.-

Table 3. *Subject anthropometrics*

	N	Age (years) Mean ± SD	Heigh (cm) Mean ± SD	Weight (kg) Mean ± SD	BMI (kg/m2) Mean ± SD
Girls	4	20.25 ± 3.40	166.5 ± 4.49	66.00 ± 14.57	23.93 ± 3.98
Boys	4	21.50 ± 2.89	178.4 ± 8.44	79.45 ± 17.97	24.63 ± 3.83
Overall	8	20.88 ± 2.99	172.4 ± 8.91	72.73 ± 16.76	24.28 ± 3.64

Each test was explained by a team of trained students from the Sports Selection and Counseling Center of the Faculty of Physical Education and Sport in Iași.

Anthropometry

Anthropometric data consisted of height measurement and body analysis. Athletes' height was measured using a Handy electronic level and Bosch GLM80 Professional rangefinder, while body analysis was determined with the Tanita BC-601 CG.

Legs explosive power/force

Explosive strength was determined by applying the Squat Jump, Countermovement Jump and Free Arms Jump protocols using the JustJump system (Probotics. Huntsxille, Alabama, USA). Between each jump the athletes had a 2-minute break. The Squat Jump was performed from a standing position with knees bent at 90° and hands on hips. After holding the position for 3 seconds, the vertical jump was performed with the hands on the hips. Countermovement Jump, similar to the previous one, the difference being the lack of the 3 second hold. The Free Arms Jump was performed from standing apart using the momentum of the arms. During the flight the knees had to be extended, and the landing had to be done on both feet for all jumps. (MDE)

Arms explosive force

Explosive upper limb strength measurement was determined using the 3 kg medicine ball. Overhead medicine ball throws were performed with both hands from a standing position with knees slightly bent, from the side by twisting the trunk, simulating the forehand shot, followed by the backhand. The distance from the throw line to the landing spot of the medicine ball was measured with the mechanical tape measure. (MDE)

Sprint 5, 10 and 15 m

Distances of 5, 10 and 15 m were demarcated on a 20-meter corridor, and timing gates with photocells were positioned. The athletes had to perform a speed run, noting the results at the mentioned distances. (MDE)

Agility 505

The 505 agility test involves running the distance of 15m, turning 180 degrees and returning to the lay line. Timing gates with photocells were positioned at the start and at a distance of 10 meters. 5 m forward and 5 m back are taken into account. (MDE)

Agility - Hexagon

The hexagon was formed from the 6-segment kit (60.5 cm long, 4 cm wide). The test involves making a jump from inside the hexagon over each of its segments and returning. The test started on the left side, changing direction to the right side when turning. The time it was performed was measured using a stopwatch. (MDE)

Speed of the tennis ball

Forehand force and ball speed were measured from semi-open and closed stances. The semi-open forehand position involves turning the shoulders perpendicular to the net. The distance between the legs was about shoulder width, with the right leg being slightly more forward than the left. The closed position is the same from the point of view of the shoulders, but the placement of the legs differs. This is the opposite of the open position, so the left leg is placed further forward than the right. 3 repetitions were performed for each position. The Stalker Sport 2 Radar was used to determine the speed.

Results

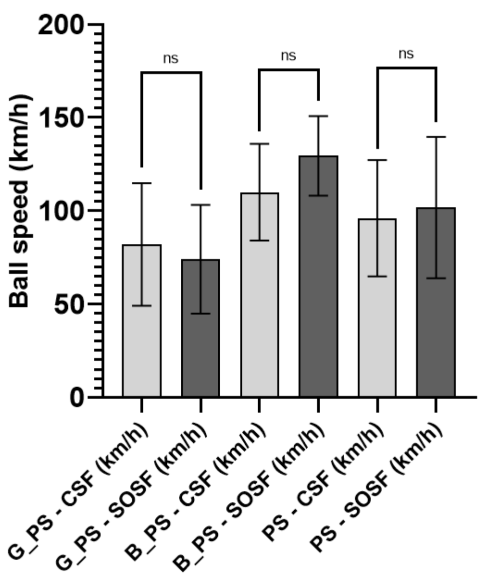
Our sample was a numerically balanced one, the interest being in the difference in ball speed between the 2 types of hitting. Table 2 shows the maximum speeds reached by balls hit by Closed Stance Forehand and Semi-open Stance Forehand.

***Table 4.** Peak speed of the ball hit through Closed Stance Forehand and Semi-open Stance Forehand*

	CSF (km/h)	SOSF (km/h)	t test
Girls (n=4)	82+32.89	74+29.13	t=1.499; df=3; p=0.231
Boys (n=4)	110+25.92	129.5+21.3	t=1.388; df=3; p=0.259
Overall (n=8)	96+31.24	101.8+37.92	t=0.662; df=7; p=0.529

The analysis was done for both genders as well as for the entire sample. A non-significant difference in ball speed was found when the hitting technique was changed. Even if statistically the results are close (Figure 3), a higher average value of the hit made by Semi-open Stance Forehand can be observed for boys (129.5+21.3 km/h) and overall (101.8+37.92 km/h).

Figure 3. Peak speed of the ball according to gender and technique



The speed of the ball after hitting could indicate the technical efficiency as well as the parameters of the physical effort involved. Therefore, the links established between the radar-determined speed and the estimated physical characteristics were measured. Pearson correlation indices were calculated according to gender and technique used (Table 3).

Table 5. *Correlation between peak ball speed în both used techniques and other measured parameters*

	G_Peak speed - CSF (km/h)	G_Peak speed - SOSF (km/h)	B_Peak speed - CSF (km/h)	B_Peak speed - SOSF (km/h)	Peak speed - CSF (km/h)	Peak speed - SOSF (km/h)
Handgrip (kg)	0.27	0.52	-0.94	0.02	0.25	0.69
SJ (cm)	0.64	0.45	0.04	-0.41	0.46	0.6
CMJ (cm)	0.85	0.71	-0.26	-0.47	0.39	0.65
CMJ-AS (cm)	0.84	0.64	0.17	-0.35	0.48	0.71*
Ball thrown over head (m)	0.48	0.33	-0.26	059	0.45	0.85***
Ball thrown FOREHAND (m)	0.96	0.84	0.52	0.57	0.52	0.78*
Ball thrown BACKHAND (m)	0.58	0.68	-0.89	0.06	0.41	0.78*
5 m (s)	0.88	0.58	-0.48	-0.34	-0.43	-0.5
10 m (s)	0.84	0.62	-0.23	-0.07	-0.43	-0.63
15 m (s)	0.84	0.63	-0.15	-0.01	-0.43	-0.66
505 (s)	0.77	0.64	0.9	0.34	-0.39	-0.68
Hexagon (s)	0.19	0.18	-0.52	0.36	-0.78	-0.75*
Peak speed - CSF (km/h)	1	0,05	1	0,3	1	0.76*

*G – girls; B – boys; CSF - Closed Stance Forehand; SOSF - Semi-open Stance Forehand; SJ - Squat Jump; CMJ - Countermovement Jump; CMJ-AS - Countermovement Jump with arm swing; * - p<0.05; *** - p<0.001.*

In the case of both girls and boys, the speed of the ball after hitting does not register significant correlations with the measured parameters. When the analysis is done on the entire sample, its correlations with some of the strength and agility parameters are established. The premise of a significant correlation between the speeds reached by the balls following the 2 types of technical executions is created (r= 0.76; p<0.05).

The speed recorded after SOSF is associated with CMJ-FA (r= 0.71; p<0.05), throwing the medicine ball in its 3 variants and the athletes' ability to coordinate within the hexagon test (r= -0.75; p<0.05) . The strongest of these links is created by throwing the ball overhead (r= 0.85; p<0.0001).

Discussion

The purpose of this preliminary study was to compare the mechanical effect that the two analyzed techniques would have on the ball. By measuring its speed with the radar we were able to estimate the impulse the missile gives it. The higher it is, the more successful the attack would be.

We hypothesized that the semi-open position would provide greater impact force, but mathematical calculations applied to our subjects contradicted the hypothesis. The results showed that there are no significant differences between the 2 hitting options. In continuation of what was discovered, we tried to identify the physical parameters of the athletes that can be correlated with the speed of the ball and implicitly the force developed during the execution.

Our sample determines by its size a limitation of the conclusions, probably the results obtained were influenced by the small number of athletes for each gender. Thus, the girls or boys did not indicate through the data provided any correlation from which to extract the physical conditioning of one or the two techniques used.

The analysis was continued for the entire sample. For Closed Stance Forehand no relationship with the proposed physical indicators was found. Instead, the Semi-open Stance Forehand had implications in interconditioning with them. The latter, with a strong effect, could have been positively influenced by the explosive force of the lower train, as well as the upper train, in addition to the coordinative capacity of the legs.

A lack of influence on handgrip strength, isolated lower body explosive strength, running speed and the athlete's ability to change direction was observed.

While our study found, after testing 8 ex-players (18-26 years old), that the semi-open forehand provided the same force as the closed, Behamonde R. (2016) found that the force of the shot is given by the optimal rotation of the trunk in accordance with the speed of the racket, regardless of the position.

The open position forehand was discovered by Martin et al. (2020) as more traumatic than the neutral forehand, the former favoring hip injuries. Consistent with another study of theirs, Martin et al. (2021) present the open defensive stance as detrimental to knee health.

Correlations are found between the grip force and the dynamic behavior of the racket. Experienced players had the tightest grip during the racket acceleration period, compared to less experienced players who had the tightest grip immediately after impact (Rigozzi, et al., 2023).

Ulbricht et al. (2016) demonstrated that the higher the level of physical training of the players, the higher the hitting force. Delgado-Garcia et al. (2019) concluded that grip strength is closely related to the force a tennis player develops in the forehand stroke, and through the medicine ball throw test, they observed that there is a correlation with the trunk turn in the backhand stroke, resulting in the speed and force of the blow.

Other specialists have deduced that there is a close relationship between 3 parameters: grip strength, running time, and player height in correlation with kick speed, suggesting that these 3 factors play an important role in creating the force required in fast kicks (Parpa, et al., 2022).

Just as in our case, Bahamonde & Knudson (2003) found no differences between the two sitting positions. Contrary to them, Muhamad et al. (2016) investigated the performance optimization of tennis players by examining the efficiency of open and closed forehands (success, accuracy). The results showed that the closed forehand has a much higher percentage of success and accuracy.

Conclusion

Closed stance forehand and semi-open stance forehand are two techniques used in the professional game of tennis with the aim of countering the opponent, giving the player time to reposition himself for future actions.

The limit given by the size of the studied sample places our analysis in the area of preliminary research. From here it is possible to check whether the semi-open position, compared to the closed one, generates a greater force through which the tennis player can create an advantage. In our case, the hypothesis was disproved, the speed of balls hit from a semi-open position being close to that generated by hitting from a closed position.

In addition to the fact that the average speed of the balls sent from the semi-opening was higher, it was found in strong correlations with the strength developed by the athlete and his coordinative ability.

Isometric hand strength, hands-free lower limb strength, movement speed, and agility did not exert a beneficial effect on our subjects' ball hitting in the presented context.

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Author Contributions

Conceptualization, M.A.C., D.E.M., O.A.D. and P.F.T.; **Resources**, D.E.M. and O.A.D.; **Methodology**, M.A.C., O.A.D. and P.F.T.; **Investigation**, D.E.M. and O.A.D.; **Data curation**, M.A.C. and D.E.M.; **Formal Analysis**, M.A.C. and P.F.T.; **Writing – original draft**, M.A.C., D.E.M. and O.A.D.; **Writing – review & editing**, P.F.T.
All authors have read and agreed to the published version of the manuscript.

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