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Do serve distance and net height modify serve biomechanics in young tennis players?

Maxime Fadier[1], Pierre Touzard[1], Chloé Lecomte[1], Benoit Bideau[1], Nicolas Cantin[2], and Caroline Martin[1]

Abstract

The aim of this study was to determine whether decreasing serving distance and net height would immediately influence serve biomechanics and performance in young intermediate tennis players. Ten young tennis players (9 to 12 years) performed maximal effort flat serves from three court conditions ("red", "orange" and "green": serving distance at 6.40, 9.00 and 11.89 m from the net and net height at 0.80 m, 0.80 m and 0.91m, respectively). A radar measured ball speed while serve kinetics and kinematics were calculated with a 20-camera optical motion capture system. Repeated measures ANOVAs were used to analyze the effect of the three conditions on ball speed, serve kinematics and kinetics. No significant differences in shoulder and elbow kinetics were observed between the three conditions. Ball speed, maximal flexion angle of the back knee and maximal angular velocities of back knee extension and trunk flexion significantly improved when players served from the red conditions in comparison with green ones. This study shows that reducing serve distance and net height may be an effective coaching strategy to immediately increase ball speed, leg drive and trunk flexion in young tennis players.

Keywords

Ball speed, kinematics, kinetics, motion analysis, racket head velocity

Introduction

The serve is one of the most important strokes in tennis. In high-level players, the ability to produce high ball speed and first serve percentage is a key element of successful play because it puts the opponent under stress and may hinder its return.[1] Many years of training are required to develop an accurate and consistent high-speed tennis serve. Reaching elite or professional levels often requires players to begin tennis training at a young age.

In accordance with studies showing beneficial effects of child-specific tennis scaling on skills development[2–5] the International Tennis Federation and national tennis organizations have proposed tennis programs with equipment (racket, ball, net and court sizes) adaptations in recent years (International Tennis Federation's "Tennis 10s Program",[6] French Tennis Federation's "Galaxie Tennis",[7] Lawn Tennis Association's Tennis for Kids Programme,[8] Tennis Australia's "MLC Tennis Hot Shots"[9]) to facilitate the long-term development of tennis players and the strokes learning. These programs proposed different tennis stages for young players based on different ball colors, court dimensions and net heights. In the French Tennis Federation's Galaxie Tennis program, the "white" stage is recommended for 5 years players who roll a white ball (20 cm in diameter, no rebound) on a small "white" court (length: 8.00 m; without net). The "purple" stage is recommended for 5–6 years players who use purple balls (20 cm in diameter, no rebound) on a small

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Petar Tudor (University of Zagreb, Hungary)

[1]M2S Laboratory, Rennes 2 University, École Normale Supérieure de Rennes, Bruz, France
[2]Ille-et-Vilaine Tennis Departmental Committee, French Tennis Federation, Rennes, France

Corresponding author:
Caroline Martin, M2S Laboratory, Rennes 2 University, École Normale Supérieure de Rennes, Campus de Ker Lann, Avenue Robert Schuman, 35170 Bruz, France.
Email: caroline.martin@univ-rennes2.fr

"white" court (length: 11.00 m; net height: 0.50 m). The "red" stage is recommended for 6–8 years players who use red balls (75% slower than yellow ones) on a small "red" court (length: 12.80m; net height: 0.80 m). The "orange" stage is recommended for 8–10 years players who use orange ball (50% slower than yellow ones) on an intermediate "orange" court (length: 18m, net height: 0.80 m). The "green" stage is recommended for 9–10 years players who use green balls (25% slower than yellow ones) on a traditional court (length: 23.77 m, net height: 0.91 m). The "yellow" or traditional stage is recommended for players from 10–12 years who use the traditional balls on a traditional court (length: 23.77 m, net height: 0.91 m).[6]

From a general perspective, reducing court size and lowering net height allows children to play tennis in a manner that more closely represents the adult or professional game[10]: more aggressive play with more groundstrokes winners,[11,12] volleys and shots played at a comfortable height.[13] Gimenez-Egido et al., (2019) evaluated the immediate effect of reducing net height (from 0.91 to 0.80 m) and court dimensions (from "green" / traditional court – 23.77 m to "orange" court – 18 m) on serve effectiveness in under 10 (U10) tennis players. They reported a greater serve effectiveness in "orange" court.[14] Moreover, other studies reported a lack of adaptation at the "green" court for under 10 years old (U10) players and at the "yellow" court for under 12 years old (U12) players. Fitzpatrick et al. (2017) compared progressive stages in simulated matches (U7 "red", U9 "orange", U10 "green" and U12 "yellow").[15] They noticed that the lowest success rate on first serves was at the U10 "green" stage. Moreover, Schmidhofer et al. (2014) compared serve statistics (aces, 1st serve percentage, double faults, 1st and 2nd serve points won) between professional players (ATP) and the best Austrian kid players of the U9, U10 and U12 age categories.[16] U9 played on an "orange" court with orange balls, U10 played on a "green" court with green balls and U12 played on a "yellow" regular court with regular balls. Results demonstrated that the U9 "orange" players have higher values in the percentage of 1st serve points won (%) than the U10 "green" (+7.6%) and U12 "yellow" players (+7.1%).[16] These results indicate lower serve effectiveness for U10 and U12 players on "green" and "yellow" courts.

Tennis coaches spend considerable time advancing specific interventions or drills in the hope of improving serve biomechanics to enhance performance and to reduce injury risks.[17] Among all the possible interventions, coaches prescribe drills with scaling constraints in the environment to facilitate skill acquisition.[10,18] During training sessions, they often ask U10 and U12 tennis players to serve closer from the net and with a lower net height[18] than recommended by the different tennis programs for kids (Tennis 10s, Galaxie Tennis, MLC Tennis Hot Shots).

While coaches are encouraged to decrease the serving distance and the height of the net to favor serve acquisition, effectiveness and offensive intentions in young tennis players,[18] the immediate effect of these scaling constraints on serving kinematics, joint kinetics, and injury risks is largely unknown and need to be considered. Consequently, the aim of this study was to determine the influence of serving conditions (serving distance and height of the net) on the serve biomechanics in young tennis players. We hypothesize that ball speed, racket velocity, upper and lower limb joint kinematics would be increased and upper limb joint kinetics would be decreased when the serving distance and the height of the net are reduced.

Materials and methods

Ten young intermediate competitive tennis players (five boys and five girls, age: 10.2 ± 1.4 years, height: 1.41 ± 0.09 m, weight: 31.8 ± 6.7 kg), with an International Tennis Number between 6 and 9 and at least 3 years of practice, participated voluntarily in this study. Eight were right-handed and two were left-handed. All the players were involved in a local training program coordinated by the Ille-et-Vilaine departmental Committee of the French Tennis Federation. All the players were used to train and compete on tennis courts with traditional dimensions (23.77×8.23 m) and with green balls. At the time of testing, all the players were considered healthy, with no history of surgery on the dominant arm. Testing was conducted in an indoor tennis court at the M2S Laboratory. Before experimentation, the players and their parents provided informed consent, medical history and were fully informed of the procedures. The study was approved by the local ethics committee and conducted in accordance with the 1975 Declaration of Helsinki. No potential conflicts of interest exist

Forty-three retro-reflective markers were placed on the player's bony landmarks and five markers were located on the racket as described in a previous study.[19] After a warm-up of at least 15 min, including general warm-up and serve repetitions (as many repetitions as needed to familiarize with the testing equipment), each player performed three successful flat serves with "green" balls from three different serving distances corresponding to the "red", "orange" and "green" courts (respectively 6.40m, 9.00m and 11.89m from the net) to the deuce service box in a randomized order. Players were asked to hit the ball as fast as possible. For the red and orange courts, the height of the net was lowered at 0.80 m, as recommended.[20] For the green court, the height of the net was fixed at 0.91m.[20]

A motion capture system with twenty cameras sampling at 200 Hz (Oqus, Qualisys AB., Göteborg, Sweden) was used to record the trajectories of the 3-dimensional (3D) anatomical landmarks. Players were shirtless or wore a bra and a tight short to limit movement of the markers. Post-impact ball speed was measured for each trial by using a radar (Stalker Professional Sports Radar, Applied Concepts, Plano, Texas, USA) fixed on tripod and placed 2 m behind the players in the direction of the serve. Radar's height on the tripod was adjusted with impact height for each player. After the capture, 3D coordinates of the landmarks were reconstructed with QTM software Qualisys AB., Göteborg, Sweden) with a residual error of less than 1 mm. The 3-D motions of each player were expressed in a right-handed inertial reference frame R1 whose origin was at the center of the baseline. X represented the baseline, Y pointed forward, and Z was vertical and pointed upward. The 3-D coordinate data of the markers were smoothed with a Butterworth low-pass filter with a cutoff frequency of 12 Hz, determined by residual analysis.[21] Different serve kinematic variables were calculated as previously described.[22] An inverse dynamics approach was used to calculate the peak of joint kinetics (forces and torques).[22,19] The serving arm was modeled as a three-link kinetic chain composed of the racket/hand segment, forearm, and upper arm. For the purpose of the study, shoulder proximal, anterior, posterior and superior forces, shoulder internal rotation torque, elbow proximal, anterior and medial forces and elbow varus torque were analyzed. The joint forces and torques obtained were first computed in the reference frame R1 and were later transformed to a series of anatomically relevant, righthanded orthogonal local reference frames at each joint. Mean kinetic peak values were normalized: forces were divided by body weight, and torques were divided by the product of body weight by height, and then multiplied by 100.[19] The moment of inertia of the racket about its mediolateral axis was computed using the parallel axis theorem and published racket ''swing weight'' data as recommended in the literature.[23] Racket moment of inertia about the long axis was calculated as reported in the literature[24]:

$$\text{moment of inertia } (kg \cdot m^{-2}) = (mass\ x\ head\ width^2) / 17.75$$

Racket moment of inertia about its anteroposterior axis was defined as the sum of the racket's other two principal moments of inertia.[24]

For each of the three serving conditions, the magnitudes of ball speed, kinematic and kinetic parameters were averaged for each player. One-way analysis of variance with repeated measures was used to analyze the effect of the three serving conditions on ball speed, serve kinematics and kinetics. When significant main effects were present, post hoc pairwise comparisons were undertaken using a Holm correction to determine the source of difference. Where data were not normally distributed, significance was determined using a Friedman analysis of variance with repeated measures on ranks and a post hoc Durbin-Conover test Post-hoc analysis with Durbin-Conover tests was conducted with a Bonferroni correction for multiple comparisons. The level of significance was set at $P \leq .05$. Furthermore, effect sizes using partial eta squared ($\eta^2 p$), defined as small (.10–.24), moderate (.25–.39), or large (≥.40), Kendall's W, defined as small (.10-.29), moderate (0.30–0.49) and large (≥0.50), and Cohen d, defined as trivial (<0.20), small (0.20–0.49), moderate (0.50–0.79), or large (≥0.80), according to the cutoffs suggested by Cohen[25] were also calculated.

Results

Shoulder and elbow kinetics

No significant differences and trivial or small effect sizes were observed for shoulder and elbow kinetics among the three serving conditions (Table 1).

Ball speed and racquet head velocity

The serving conditions significantly and moderately affected ball speed ($\chi^2(2) = 8.36$; $P = .014$; $W = 0.418$) that was significantly lower in green compared with red conditions ($P = .006$; $d = -.636$, moderate effect). There was also a tendency toward a difference concerning ball speed between green and orange conditions ($P = .084$; d = -.745, moderate effect).

The results showed a significant and moderate main effect of the serving conditions on maximal racquet head velocity ($F(2,18) = 5.02$, $P = .018$, $\eta_p^2 = .358$). Post hoc analysis revealed a moderate but not significant effects for maximal racquet head velocity between red and orange conditions ($P = .104$; $d = .734$, moderate effect) and between red and green conditions ($P = .104$; $d = .786$, moderate effect) (Table 2).

Kinematics

The serving conditions significantly and moderately affected the angle of maximal back knee flexion ($\chi^2(2) = 8.60$; $P = .014$; $W = 0.430$). Maximal back knee flexion was significantly lower in green conditions than in red conditions ($P = .006$; $d = .782$, moderate effect) (Table 2). Post hoc analysis revealed also a tendency toward a large difference concerning the angle of maximal back knee flexion between green and orange conditions ($P = .111$; $d = .891$, large effect) (Table 2).

The results showed a significant and moderate main effect of the serving conditions on maximal velocity of back knee extension ($F(2,18) = 3.99$, $P = .037$, $\eta_p^2 = .307$). The maximal velocity of back knee extension was significantly lower in green conditions compared with orange ($P = .048$; $d = -.935$, large effect) and red conditions ($P = .050$; d = -.745, moderate effect).

The results showed a significant and large main effect of the serving conditions on maximal velocities of trunk

Table 1. Maximum shoulder and elbow kinetic values for different serve conditions (mean ± SD).

	Green	Orange	Red	*F (2,18)*	*P* value	Effect size η_p^2
Shoulder kinetics						
Proximal force (N.kg^{-1})	3.5 ± 1.0	3.6 ± 0.9	3.8 ± 1.1	1.430	0.275	0.137
Anterior force (N.kg^{-1})	2.3 ± 0.6	2.5 ± 0.5	2.4 ± 0.5	0.929	0.150	0.094
Posterior force (N.kg^{-1})	2.3 ± 0.5	2.5 ± 0.6	2.5 ± 0.5	0.315	0.734	0.034
Superior force (N.kg^{-1})	2.6 ± 1.0	2.9 ± 0.9	2.7 ± 0.7	1.85	0.186	0.171
Internal rotation torque (N.m.kg^{-1}.m^{-1})	45.2 ± 7.6	47.0 ± 8.1	48.2 ± 8.0	0.464	0.636	0.049
Elbow kinetics						
Proximal force (N.kg^{-1})	4.2 ± 0.8	4.2 ± 0.6	4.2 ± 0.8	0.062	0.940	0.007
Anterior force (N.kg^{-1})	1.2 ± 0.3	1.3 ± 0.5	1.3 ± 0.5	2.34	0.125	0.206
Medial force (N.kg^{-1})	1.9 ± 0.7	2.0 ± 0.3	2.0 ± 0.5	0.137	0.873	0.015
Varus torque (N.m.kg^{-1}.m^{-1})	49.2 ± 8.0	49.0 ± 8.2	50.7 ± 7.8	0.057	0.944	0.006

Table 2. Serve performance and kinematics for the different serve conditions (mean ±SD).

	Green	Orange	Red	Main effect *P* value	Effect size η_p^2 *or W*
Ball speed and racquet velocity					
Ball speed (m.s^{-1}) *	**26.5 ± 3.7** $	**27.6 ± 3.3**	**27.8 ± 3.2**	**0.014**	**0.418**
Maximal racquet head velocity (m.s^{-1}) *	**26.6 ± 2.9**	**27.1 ± 2.8**	**28.1 ± 3.0**	**0.018**	**0.358**
Maximal angles					
Back ankle flexion (°)	80 ± 6	80 ± 6	81 ± 5	0.736	0.033
Front ankle flexion (°)	78 ± 6	79 ± 8	79 ± 7	0.363	0.106
Back knee flexion (°) *	**127 ± 21** $	**124 ± 20**	**123 ± 19**	**0.014**	**0.430**
Front knee flexion (°)	119 ± 10	118 ± 11	121 ± 11	0.135	0.199
Maximal velocities					
Back ankle extension (°.s^{-1})	531 ± 174	531 ± 164	527 ± 163	0.981	0.002
Front ankle extension (°.s^{-1})	460 ± 131	478 ± 92	473 ± 118	0.421	0.045
Back knee extension (°.s^{-1}) *	**385 ± 221** &$	**442 ± 235**	**446 ± 226**	**0.037**	**0.307**
Front knee extension (°.s^{-1})	458 ± 174	484 ± 167	464 ± 167	0.311	0.122
Trunk flexion (°.s^{-1}) *	**247 ± 63** $	**263 ± 54**	**275 ± 66**	**0.002**	**0.511**
Upper trunk longitudinal rotation (°.s^{-1})	626 ± 138	638 ± 136	661 ± 154	0.378	0.102
Pelvis longitudinal rotation (°.s^{-1})	534 ± 135	549 ± 144	576 ± 154	0.176	0.176
Shoulder internal rotation (°.s^{-1})	1603 ± 569	1644 ± 613	1771 ± 546	0.273	0.130
Upper arm pronation (°.s^{-1})	1331 ± 696	1407 ± 749	1473 ± 739	0.263	0.174
Shouder-over-shoulder rotation (°.s^{-1})	136 ± 59	150 ± 59	141 ± 63	0.376	0.103
Elbow extension (°.s^{-1})	1027 ± 333	1057 ± 339	1081 ± 321	0.194	0.167
Wrist flexion (°.s^{-1})	1581 ± 174	1614 ± 224	1601 ± 214	0.546	0.065

*: significant main effect between serve conditions ($P < 0.05$). $: significantly different from green and red ($P < 0.05$). &: significantly different from green and orange ($P < 0.05$).

flexion ($F(2,18) = 9.39$, $P = .002$, $\eta_p^2 = .511$). The maximal velocity of trunk flexion was largely lower in green conditions compared with red conditions ($P = .004$; $d = -1.48$, large effect). There was also a tendency toward a difference concerning maximal velocities of trunk flexion between green and orange conditions ($P = .060$; $d = -.815$; large effect) (Table 2).

No significant differences and trivial or small effect sizes were displayed between serving conditions for maximal angles of back and front ankle flexion, maximal angle of front knee flexion, maximal velocities of front knee extension, back and front ankle extension, upper trunk longitudinal rotation, pelvis longitudinal rotation, upper arm pronation, shoulder over shoulder rotation, elbow extension, wrist flexion and shoulder internal rotation (Table 2).

Discussion and implications

Red conditions

The study supported the hypothesis that serve ball speed, maximal back knee angle flexion, maximal velocities of back knee extension and trunk flexion are affected by a red smaller court and net sizes (length 12.80 m, net height 0.80 m) in a sample of 9 to 12 years old tennis players. Indeed, our results show a moderate and immediate increase in ball speed (+ 1.3 m.s^{-1}, + 5%) when players serve in comparison with the green one. This result is in line with previous results showing that reducing court dimensions contributes to improve the stroke performance of young tennis players (i.e. high increase in a velocity-precision score, + 13.0% of overall success rate in groundstrokes[26] and + 12.8% of total serve points won.[27])

The rationale for scaling sport is predominantly underpinned by an ecological dynamics viewpoint of human movement and skill acquisition.[28] Ecological dynamics advocates that an individual's behavior emerges from the self-organization of perception and action under interacting constraints (organismic, environmental, and task). Indeed, the constraints imposed by sport (e.g. court size, net height, balls and racket properties in tennis) determine the boundaries of what actions are possible.[29] Vaverka Cernosek[30] (2013) hypothesized that young and shorter tennis players intuitively increase the ball speed based on their individual experience because they perceive that the service area into which the ball can land is higher and increases their probability of successful execution in red and orange conditions. This phenomenon could be related to the study of Whiteside et al. (2013) that underlined that tennis serve outcome appears most closely related to the projection angle of the ball.[31] At a given forward and impact height, the margin for error in the projection angle decreases as ball velocity increases. As a consequence, young tennis players need more to adjust projection angle-ball speed combinations to overcome the net than adults due to their lower stature and impact height.[31] In our study, ball impact was not measured but it is well known that when the ball is hit at a higher and/or forward contact point into the court, there will be a larger "window" of initial projection angles for the serve to clear the net and land in the service box.[31,32] Concerning the window of initial projection angles, the proportion between the red serve positions and the players' body height is more favorable.[33] The mean body height of U12 players is only 78% of the adults' body size and the distance between the net and the red baseline is respectively 46% of the distance between the net and the traditional court baseline.[27] As a consequence, in red conditions, the margin for error in the projection angle for a given impact height would be increased[32,34] allowing young players to hit more powerful serve. Conversely, due to their smaller body height, young tennis players are not able to intend and produce movements corresponding to an aggressive serve when they serve from the green court.

The higher ball speed measured in red conditions is probably also the result of kinematic changes measured between serving distances. Our results show that both reducing serving distance and net height promote a more dynamic engagement of the back leg in young tennis players, which is reflected in increases in maximal back knee extension velocity (+ 61 °.s^{-1}, i.e. + 15.8% in red) and higher knee flexion angle (+ 4° in red) in comparison with green conditions. These kinematical parameters have previously been related to effective lower limb involvement and higher ball speed.[35,36] Indeed, to improve ball speed, tennis players need to produce an efficient leg drive based on an effective back knee flexion and then a vigorous knee extension.[35,36] One may hypothesize that the storage of elastic energy and muscle preload in the back leg may be improved during red conditions. By increasing the action of the leg drive, young tennis players could be able to transfer a little bit more force to the trunk and the dominant upper limb. Optimizing leg drive and vertical ground reaction forces may have also favored and help the trunk forward rotation.[37] Our findings support this hypothesis because they show a significant and large main effect of the serving conditions on maximal velocities of trunk flexion. Effect size reveals that maximal angular velocities of trunk flexion is largely improved in red conditions (+ 11.3%). The immediate improvements in maximal back knee extension and trunk flexion velocities and in maximal knee flexion angle measured in "red" conditions appear pragmatically meaningful in serve skill development. Indeed, Whiteside et al. (2013) showed an evolution in the tennis serve kinematics from prepubescence to adulthood in female tennis players. Specifically, maximal back leg extension velocity and trunk variables increase with age between pre-pubescents, pubescents and adults, allowing players to achieve higher ball speeds in the serve.[38]

Reducing the serve distance and net height has only small effects on shoulder internal rotation, shoulder-over-shoulder rotation and upper arm pronation angular velocities. This can be explained by the immature serve technique of the young tennis players in our study. Indeed, it has been reported that shoulder-over-shoulder and shoulder internal rotation were reduced in pre-pubescent players who relied more on twist rotation of the trunk.[38] This is the case in our study as evidenced by the maximal value of pelvis and shoulder longitudinal angular velocities higher than those reported for adult players in the literature.[38] Even if the back leg drive is moderately improved for red conditions, it still be insufficient for inducing an efficient and significant shoulder-over-shoulder and shoulder internal rotations in young tennis players.

Results show that serve conditions demonstrated only trivial or small effects on shoulder and elbow kinetics in young tennis players. This contrasts with our initial hypothesis (i.e. decreases in upper limb joint kinetics with decreases in serving distance and net height) and the study of Fleisig et al. (2018)[39] reporting that an increased pitching distance was associated with higher shoulder kinetics in young baseball players. The difference of findings may be related to the fact that the pitching distances in young baseball players were much more extreme (14.02m, 16.46m and 18.44m from the home plate) than our serving distances (6.40 m, 9.00 m and 11.89 m from the net). Fleisig et al. (2018)[39] reported that at farther distances youth pitchers significantly increased their effort, and as a consequence, their shoulder kinetics to reach the home plate. However, the current finding is congruent with another study in baseball that did not find relationship between varying pitching distance (18.44m, 19.05 and 19.41m) and joint kinetics in adult players.[40] Our results show that in red conditions, young tennis players are more efficient because they reach higher ball speed without overloading both their shoulder and elbow compared to green condition.

Our current data show an immediate ball speed increase in our sample of 9 to 12 years old boy and girl tennis players when they serve from the red court. This result is consistent with previous results showing that U10 players serving from the baseline (11.89m from the net) won a lower percentage of serve points, hit less aces and unreturned serves that U10 players serving inside the tennis court (9 m and 10.39 from the net).[27,41] The results of the current study provide preliminary support for the use of a reduced serve distance and net height as a coaching tool in young tennis players to moderately increase ball speed ($+1.3\ m.s^{-1}$) and to moderately or largely improve maximal angular velocity of trunk flexion as well as leg drive. Moreover, we could assume that the improved serve performance (ball speed and efficiency) in red conditions may logically have a positive impact on young tennis players' confidence and motivation, enhancing participation and engagement, as explained in the literature.[13,26,3] Decreasing serve distance and net height during training and/or competitions may be helpful in long-term skill development because, without increasing the loads on their dominant upper limb, it would help players to start the points with more aggressive tactical intentions from the serve, which are typical of professional tennis game.[42] However, this hypothesis requires future longitudinal research to confirm this. A reduced serve distance and net height would also decrease the time available to the returner to see and react to the serve and to develop crucial skills (i.e. reaction time, visual strategy, and anticipation) for an efficient return in young tennis players: reaction time, visual strategy, and anticipation. When they serve from a closer distance from the net and with a lower net height (especially in "red" conditions), our results show that young tennis players experience a more mature serve technique for which several kinematical values (angular velocities of knee extension and trunk flexion) are closer than those measured for older ages and higher practice level.[43,38] However, we do not know if regularly practicing the serve in reduced distance and net height conditions could accelerate the acquisition of a more correct and mature serve technique and would have a beneficial effect on retention and transfer to "green" conditions. Further works are needed to evaluate this question.

Orange conditions

Concerning the orange court, the statistical analyses show only one significant and large increase in maximal velocity of back knee extension in comparison with green court. Our results also show moderate and large increases in ball speed, maximal angle of back knee flexion and maximal velocity of trunk flexion but these differences are not statistically significant; only tendencies are observed for these variables with P values close to the level of significance. This probably happens because our sample size is too small.

Limitations of the study

In addition to decrease the ability to detect differences across the court conditions (orange vs. green), the small sample size of this exploratory study also increases the chance of type II errors and decreases statistical power. The current sample size is limited because we included only young tennis players; moreover, their participation was voluntary and submitted to their parents' consent. Similarly, given the small sample size, the current study lacks generalizability and thus serves to encourage future work to examine and confirm the immediate and positive effect of the orange court on ball speed and serve kinematics on larger or different tennis playing cohorts.

Perspectives and future directions

In the literature, it is known that serve kinematics and kinetics are different between flat, slice and kick serves.[44] Further research should examine the kinematic and kinetic changes for other serve types from varying distances. In this study, we decided to test the combined effect of three serve distances and two net heights in accordance with the different scaled courts ("red", "orange", "green") from different tennis training programs.[20] In the literature, previous research analyzing the playing structure in young players identifies a severe problem at the transition from the "orange" court to the "green" court.[16] Consequently, an intermediate stage, called "lime" court with a baseline located at 10.39 m from the net (between orange and green courts) was introduced in the Austrian Tennis System but not in the ITF Tennis Play & Stay Program.[27] Future research should take into account this new serve distance and should evaluate the effect of an ideal resized serve distance based on the average body heights of the players involved in the experimentation. In this study, we decided that players served only with "green balls" which are 25% slower than yellow ones. A previous study showed that the use of a green balls increased rally speed, allowed players to strike the ball at a lower (more comfortable) height on their groundstrokes and increased the number of balls played at the net.[45] However, this study showed that ball compression had no effect on the relative number of winners, forehands, backhands, first serves in and double faults. It would be interesting for future researches to evaluate the combined effect of different ball types ("red", "orange", "green" and "yellow") and different court dimensions on upper limb joint kinematics (shoulder internal rotation, upper arm pronation, wrist flexion…) and upper limb kinetics at impact.

Practical applications

From a practical point of view, our results show that reducing the serve distance and the net height appears to be a relevant drill to use when a young player has difficulty pushing upwards with the legs and/or rotating forwards with the trunk during the serve. Smaller serve distance and lower net height could also be used when young players fail to hinder the returner because theirs serves lack of speed. For example, to create a positive dynamic about the serve, a new experimental rule has been created and tested ("the forward serve") by the Tennis Brittany League (France) during the 2022 local Galaxie Tennis competitions for young players called the "Breizh Tour".[46] In these competitions, young tennis players at "orange" and "green" stages were allowed to serve from the "red" and "orange" serve lines, respectively. During some of these competitions, the number of aces per match has been counted. For example, during an "orange" and a "green" Galaxie Tennis competition of the Breizh Tour with the permission to serve closer from the net ("forward serve"), the young players hit on average 0.97 aces / match and 0.38 aces / match, respectively.[47] Although these results have not been published, they are strongly higher than those of Schmidhofer et al. (2014) who reported 0.21 ± 0.51 aces / match for "orange" competitions and 0.04 ± 0.20 aces / match for "green" competitions in young tennis players without specific serve distance adaptations. This new initiative of "forward serve" is very encouraging with regard to serve efficiency and motivation in young tennis players and could be subject to scientific studies in the future.

Conclusion

In conclusion, the current study shows that a decrease in serving distance and net height has trivial or small effects on serve kinetics but moderate positive effects on ball speed in the serves of 9 to 12 years old tennis players. Moderate positive effects are also observed for leg drive kinematics when young tennis players serve closer to the net from the red court. A large positive effect is also reported for maximal velocities of trunk flexion for the red conditions. As hypothesized by Gimenez-Egido (2020),[41] our study shows that modifying key constraints of the environment (smaller serve distance and lower net height) constitute a favorable approach for practitioners that simplifies serve action, improve serve performance and provides more learning opportunities to explore new movements patterns and kinematics as happens at other ages and stages.

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ORCID iD

Caroline Martin https://orcid.org/0000-0002-4114-8947

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