Standardized Testing of Forehand and Backhand Groundstrokes in Tennis through a Bird’s Eye Perspective.

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ABSTRACT
There is evidence in the tennis literature showing that angular momentum about the longitudinal body axis has an important impact on the ball velocity in groundstrokes. However, the angular momentum about this body axis has so far only been estimated with time consuming 3D-video analyses through an examination of the maximal angular displacement of the shoulder axis towards the baseline. In contrast, a simple and inexpensive method is introduced to examine this angular amplitude about the longitudinal body axis from a bird’s eye view. Six girls and twelve boys between 10 and 12 years with different tennis expertise participated in the study. Forehand and double-handed backhand strokes from the baseline were videotaped for a kinematic analysis. While maximal trunk rotations reached average angles of 105 degrees in forehand strokes and 120 degrees in backhand strokes highly significant correlations between ball velocity and the trunk rotation (forehand strokes: r = 0.65 and backhand strokes: r = 0.76) were found. This result shows that the trunk rotation is clearly more important for the backhand than for the forehand stroke. Other angular displacements (trunk torsion and racket orientation) did not prove to be as important for the stroke velocity.

Key words: Angular momentum, Trunk rotation, Kinematic analysis, Bird’s eye perspective.

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INTRODUCTION
Angular momentum about the longitudinal body axis generated by the players’ stroking pattern plays an important role in the acceleration of the tennis ball during the contact phase in the baseline strokes (Bahamonde & Knudson, 1998; Knudson, 2001; Bahamonde & Knudson, 2003; Elliott, 2006). Although there are some indications in the literature about its particular importance for the different stroking techniques (e.g. Reid & Elliott, 2002) it is still open to what extent the angular momentum is influencing performance in the forehand and the backhand in general (Bahamonde & Knudson, 2003). In addition, an analysis of the angular momentum through biomechanical methods remains to be a complicated procedure. Up to date, respective studies on the trunk rotation in tennis were pursued with time-consuming 3D-film analyses while using the angular displacement between the shoulder alignment and the baseline as an estimate for the amount of angular momentum (e.g., Elliott et al., 1997). While study by Elliott and colleagues had a real game situation as the main objective, coaches and tennis players find it useful to examine trunk rotation for a regular skill testing under standardized conditions as well. For that purpose, online-information rather than time-intensive 3D-analysis is required. We have used a video camera from a bird’s eye position right above the player to match the requirements for an online-information system. The same idea was used by Elliott and co-workers (Elliott et al., 2002) to measure the shoulder alignment in cricket fast bowling. However, Elliott and co-workers examined the shoulder alignment towards the longitudinal body axis as a main incentive while the testing criteria of our study related to the shoulder alignment and the racket orientation towards the baseline.

For the standardization of our performance test, subjects were asked to return tennis balls played by a ball machine towards the centre of the baseline with forehand and back strokes in alteration. While ball velocity was used as a criterion measure, we analysed trunk rotation and racket orientation towards the baseline as dependent measures.

METHODS
Six girls and 12 boys (10 to 12 y, 152 ± 6 cm, 39 ± 6 kg) participated in the study. Their expertise in tennis varied from
belonging to the regional best players, the local best players or
they merely played in kids tennis teams while ranked among
the first two team positions. All subjects were easily mastering
the two groundstroke techniques.

The video recordings were done on an indoor court with a
wood-frame roof construction. Forehand stroke and double-
handed backhand strokes were recorded through a firewire
cable on a laptop hard drive and evaluated with a film analysis
software (SIMI Reality Motion System, Unterschleissheim,
Germany) consecutively. The video camera (Sony VX-1000E,
shutter opening time 1/5000 s with 50 frames/s) was attached
to the roof construction 4,5 m above the middle of the baseline
and perpendicular to the court surface. A remote control was
used to operate the camera. An evaluation area was calibrated
with the size 3,50m x 3 m.

While the tennis balls were played towards the subjects with a
ball machine with approximately 7,3 m/s (average across five
frames before the racket contact) at 0,4 to 0,5 balls per second,
players were asked to hit the balls down the line towards a
circular target areas (1,5 m diameter) in the corner of the
opposite court. Fig. 1 shows a sketch of the experimental setup.
A total of 15 forehand strokes and 15 backhand strokes were
evaluated. Forehand strokes and backhand strokes were played
in an alternating sequence. For both stroke techniques the six
most precise trials concerning the target area were used for the
statistical analysis. For each trial, video material was analysed
between five frames before the first appearance of the tennis
ball in the video image until the first frame after its
disappearance. For each trial and depending on the individual
movement velocity, 400 of the 500 ms of the video recording
were analysed.

Only the players’ angular information regarding trunk rotation
and racket orientation was collected throughout each trial. For
the trunk rotation, the maximal angle between the shoulder
alignment and the baseline was evaluated. For the racket
orientation, the maximal angle between the racket midline and
the baseline was examined (Fig. 2).

While the racket midline was captured by a digitization of the
racket top and the racket grip white circular markers were
attached to the shoulertops to indicate the shoulder
alignment. Only the perpendicular projections of the lines
captured through the above point were evaluated by our
method of analysis.

Aside from the angular information on the players stroking
performance, the tennis ball velocity after the racket contact
was analysed as a criteria for the correlation analysis. While the
outgoing tennis ball velocity after the racket contact was
calculated as the mean for all frame-to-frame velocities after
the racket contact until disappearance of the ball on the video
images, the incoming tennis ball velocity was analysed along
the passage of the ball up to the racket contact for a control.

For the statistical analysis, mean values, standard deviations,
and coefficients of variation for each subject concerning the six
trials for the forehand stroke and the backhand stroke were
calculated. Further on, individual mean values were used to
calculate group mean values. Individual mean values were also
used to test for Pearson correlations coefficients between the
angular displacements and the tennis ball velocity. Finally,
multiple correlation coefficients were calculated to determine
the variance in the tennis ball velocity explained by the angular
stroke performance data. The level of significance was set to
0,05. All statistical calculations were executed with SPSS V12.0.

Results:

All mean values and standard deviations for the outgoing ball
velocities and angular displacements evaluated are listed in
Tab. 1. A mean tennis ball velocity of 28,9 m/s was found across
all subjects tested. Maximal velocities for individuals were
found to reach up to 38,9 m/s for the forehand stroke. For the
backhand stroke, mean tennis ball velocities across all subjects
were found at 28,1 m/s. Maximal velocities for individuals were
found at close to 50 m/s for the backhand stroke. For a
comparison, ball velocities of about 66,7 m/s for adult players
with an average skill level are reported in the literature while
playing the balls at 25 m/s to the subjects with a ball machine (Mavvidis et al., 2005).

Two typical examples for the amplitude of the countermovement in a forehand stroke (left side) and a double-handed backhand stroke (right side) are shown in Fig. 3, both depicted from a female local class player. While the player reveals a somewhat open stance in the forehand stroke a rather closed stance can be seen in the backhand stroke. Both images nicely illustrate how far the trunk is rotated towards the baseline.

The group mean for the maximal shoulder alignment versus baseline across all subjects was found to be 104 degrees for the forehand stroke with more experienced players showing larger trunk rotations. For a reference, Bahamonde and Knudson (2003) report values of about 100 degrees. While difference in the scatter of the data were found across all subjects, individuals themselves performed their strokes in a relatively consistent manner (mean coefficient of variation across all subjects: 5.4 percent). Moreover, a highly significant correlation coefficient was found between the maximal amplitude of the trunk rotation and the tennis ball velocity ($r = 0.65$). This measure was calculated for the individual means across all subjects.

For the backhand stroke, the overall mean comes to approximately 121 degrees which is almost 20 degrees more than in the forehand stroke (see Fig. 3). Again, more experienced players showed larger trunk rotations. For a comparison, Elliott and co-workers reported values of 127 degrees (Elliott et al. 1989; Elliott & Christmass, 1995) with rackets almost parallel to the baseline our subject shows an even more pronounced racket position. For the backhand stroke, the maximal amplitude in the trunk rotation (about 125 degrees) and the maximal amplitude in the racket orientation (about 140 degrees) are observed approximately 150 ms prior to ball contact. At the instant of ball contact, the shoulder alignment as well as the racket midline are rotated towards the baseline by approximately 45 to 50 degrees.

Aside from the subject shown in Fig. 3 and Fig. 4, mean values for the maximal racket rotation were found at about 140 degrees for the forehand stroke and 130 degrees for the backstroke across all subjects. There was a tendency showing larger maximal racket rotations in the more experienced tennis players. The correlation between the racket orientation and the ball velocity across all subjects was found to be significant with $r = 0.52$ in the forehand stroke and a highly significant $r= 0.66$ for the backhand stroke.

In addition to bivariate correlations, multiple correlations were used to estimate the compound meaning of the trunk rotation (estimated by the shoulder alignment versus the baseline) and the racket orientation (estimated by the racket midline versus baseline) for the stroke velocity. As much as 43 percent (adjusted 35 percent with Multiple R = 0,66) of the variance in the stroke velocity was explained for the forehand technique. For the backhand stroke, a considerable 64 percent of stroke velocity (adjusted 59 percent with Multiple R = 0,80) was explained by the above predictors.
Discussion and Implications:

Our study showed that standardized testing of forehand and backhand groundstrokes maybe be easily achieved through a bird’s eye perspective. Most important, our study clearly revealed the trunk rotation to be larger and far more important for the double-handed backhand stroke as compared to the forehand stroke. Although the different meaning of the trunk for the two stroke techniques was already assumed in the review by Bahamonde und Knudson (2003:69) our relationships were much larger than reported in the study by Knudson and Bahamonde (1999). However, this observation might be due to a sampling effect. As the subjects in Knudson & Bahamonde study should be considered as a homogenous subgroup with little interindividual variation our subjects should be thought of as a rather heterogeneous sample favouring larger correlation coefficients. Nevertheless, all results on the relationship between the trunk rotation and the stroke velocity should be interpreted such that much emphasis should be paid for this movement feature for the teaching of beginners as well as for the training of advanced tennis players.

It may be surprising, that 10 to 12 year old tennis players do show a backswing movement comparable to experienced players examined in other studies. However, it has to be kept in mind that a laboratory setup with a ball machine was used rather than a real game situation. Therefore, stroke production was somewhat easier in our study as compared to a competitive setup. Moreover, while pre-teenage players do show similar maximal backswing amplitudes in the forehand and in the backhand the swing dynamics should be considered as well. In addition, incoming balls were played at a moderate speed such that participants could properly set up. Presumably, they would change their backswing pattern when faster incoming balls were to be played. Therefore, a challenging test to evaluate the backswing movement should encompass at least three different velocities and frequencies for the incoming balls. We predict that highly skilled players will be able to keep their backswing amplitudes in high-speed test situations rather than players with less tennis expertise.

While the bird’s eye perspective offers new insight to the players strokeing patterns, the method itself deserves some notice. For the trunk rotation, Elliott and co-workers (Elliott et al., 2002) did show substantial differences between a 3D-analysis and the bird’s eye perspective for the time course of the cricket fast bowling movement. However, main differences were found for the beginning and the end of the throw only when bowlers should a somewhat slanted body posture. In contrast, at backfoot impact, associated with a rather upright body posture, a strong correlation was found between the thorax alignment and the three- (r=0.97) and the two-dimensional (r=0.87) shoulder alignment estimations. In other words, with an erect rather than a slanted body posture trunk rotation may be well estimated through a bird’s eye perspective.

SUMMARY

The trunk is the largest segment of the human body with the largest moment of inertia. Therefore, it can generate tremendous amount of angular momentum about all body axes. The angular momentum about the longitudinal body axis is of particular importance for the stroke production in the tennis groundstrokes. This study showed how trunk rotation can be evaluated through a standardized test to estimate the amount of angular momentum about this principal body axis. A video analysis through the bird’s eye perspective is suggested to gain useful information for practise and for a technical analysis. Moreover, this system can be used as for an online feedback to a learner. Our data showed the trunk rotation to be larger and far more important for the double-handed backhand stroke as compared to the forehand stroke.

REFERENCES


