STRESS STUDIES IN TENNIS – DIFFERENCES BETWEEN TENNIS RACKETS OF DIFFERENT LENGTHS

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INTRODUCTION: Recently several manufacturers of tennis rackets have been offering elongated rackets. The extension of these rackets ranges between 1 and 5 inches. The resulting total lengths are then approximately 27 to 32 inches. The racket types are advertised as having more favorable playing characteristics (increased acceleration, higher shot force, higher service velocities, etc.). Considering the biomechanical characteristics of handling and efficiency of shot of these "Long-Bodies" shows the following suppositions:

- With equal body-segment-velocities the longer lever results in an increased velocity of the racket head.
- For the realization of both equal body-segment-velocity and an increased velocity of the racket head, the player requires more power within one shot cycle than is the case with standard racket lengths.
- In case the muscle power per time unit which has to be used with standard racket lengths cannot be further increased, the timing must consequently be adapted so that the same body-segment-velocities can be realized.

These biomechanical considerations show both positive and negative consequences. It can be assumed that not just positive consequences will appear when using "Long-Bodies". Regarding these suppositions in this study, the following parameters in the use of tennis rackets with different lengths were investigated: first, impact points on the tennis rackets, second, impact points in the field, muscle actions during the strokes, accelerations of the tennis racket handles during impact, velocities of the balls.

METHODS: A better quality player was asked to play 30 forehand ground strokes with each racket length. The maximum height to play over the net was limited with the help of an additional marking. In the field a hit zone of 2m x 2m was marked. The player had to aim at this field. The use of a ball machine guaranteed standardized passes of the balls. Between the data collection of the samples the player had time to relax. Effects of tiredness could thus be eliminated.
The first impact points were recorded with a newly developed measuring device, the Treffpunkt-Analyzer. This measuring equipment allows very fast recording of the impact point on the racket. The measuring principle is based on the use of infrared vanes. The signals of the infrared vanes are passed via cable to a special data handling box which is fixed on a belt at the player's hip. From there data are transmitted via radio to a special receiver connected with a standard notebook PC. The data processing (data storage, online-statistics, visualizing of the impact points and the possibility of acoustic online feedback) is done with Treffpunkt-Analyzer-Software. Rackets of each length (27”-rackets, 29”-rackets, 32”-rackets) were prepared with this system. The system changes the playing characteristics only

insignificantly. Players who played with this system adapted very quickly to the handling.

The second impact points were recorded via standardized observation. Two observers recorded the second impact points in the field and the flight of the ball regarding the marked zones.

The accelerations were recorded with a three-dimensional accelerometer. For this we used three accelerometers type Brüel & Kjaer 4375 mounted on small aluminium cubes. The signal of the accelerometers were provided via special charge amplifiers. For the AD-Transformation we used a 12 bit PCMCIA-Card type Data Translation DT 783. We used a sampling rate of 10000 Hz per each channel. The data evaluation was realized by using the software tool HP VEE 4.0. The statistics were performed with a standard statistics package. The fixing of the accelerometers was always at the same distance (30mm) from the end of the racket handle. The maximum values in each direction were evaluated.

For the EMG recordings we used a 25 Channel EMG recorder type MC_EMG by Multi Channel Systems. This system has a very high input impedance of 1 MOhm, so that the preparation of the skin was very easy (the skin must only be shaved). The electrodes we used had been ECG electrodes from Medicotest. We recorded the activities of the following muscles: M. deltoideus. acromialis., M. pectoralis. major sternocostalis., M. pect. major clavicularis., M. tricepis. medialis., M. trapezius. ascendens., M. teres minor, M. trapezius. transversalis., M. trapezius. descdens., M. latissim. dorsi, M. serratus. anterior., M. teres major, M. deltoideus. clavicularis., M. tricepis. lateralis., M. deltoideus. spinalis., M. bicepis., M. extensor. carpiulnaris., M. flexor. carpiradialis., M. extensor. digitorum., M. flexor carpiulnaris, M. palmaris longus, M. pronator teres, M. brachioradialis, M. policis brevis. We used a sampling rate of 5000 Hz per each channel. The EMG recordings and the recording of the acceleration were synchronized for the purpose of data relation. The preprocessing (filtering, smoothing) of the signals follows the common descriptions of the literature. The evaluation of the EMG signals includes a comparison of the following parameters: on-/ off states determined via borders gotten from a 10% clip lower regarding the maximum value of the signal, difference of the maximum value of signal from the maximum value of the acceleration, integral of the signal regarding the time 0.5 sec before and after the maximum value of the acceleration signal.

The determination of the ball velocities was realized by using a cinematographic procedure. For this we used a SVGA high-shutter camera. The shutter was set to 2000 Hz. The camera was placed vertical to the playing plane. The scene covered the first impact and the distance of 250 cm after the first impact. For the digitalization of the pictures we used a specific software package.

RESULTS AND CONCLUSIONS: The investigation shows different results regarding positive and negative effects in the use of different racket lengths. The acceleration of the racket handle is more dependent on the stiffness of the racket than on the length. We measured a 70g positive and 62g negative maximum mean acceleration along the vertical axis by using the 32" racket, 62 g positive and 61g negative maximum mean using the 29" racket and 102 g positive and 106g negative maximum mean acceleration by using the 27" racket. The difference between the 27" and the 32" racket resp. the difference between the 27" and the 29" racket is highly significant (Sig. 2-tailed: 0<.005). The 29" racket shows a (Sig.

2-tailed: 0.001 - 0.009) higher maximum mean (129 g pos./134 g neg.) along the longitudinal axis than the 27" racket (110 g pos./ 123 g neg.) and the 32" racket (105 g pos./ 100 g neg.). The differences between the accelerations along the lateral axis are insignificant. A noteworthy difference (Sig. 2-tailed: 0.012) could only be found between the 32" racket (64 g pos.) and the 27" racket (82 g pos.). A clear increase in accelerations dependent on the racket-length could not be found. The remarkably higher accelerations are probably determined by other properties of the racket, for example, a higher stiffness or a higher string tension.

The velocities of the balls are significantly different (Sig. 2-tailed: < 0.0005). The longer rackets produce higher ball velocities (27" -> 101.6 km/h, 29" -> 107.7 km/h, 32" -> 107 km/h). There is no significant difference in the ball velocities between the 29" racket and the 32" racket. It must be stated that this result is only valid for the specific playing situation of the test. It is not valid for situations like the serve.

The first impact points are different (Sig. 2-tailed: 0.005). When using the 27" racket the first impact points are located nearer (ca. 10 mm) to the racket head. Differences in precision regarding the second impact points in the field could not be found.

The EMG evaluation shows that the player using longer rackets does not need generally "more" muscle activity than using the 27" racket. Using 27" rackets significantly increased integrals of the EMG signals (Sig. 2-tailed: 0.001 - 0.05) could be found for the following muscles: M. deltoideus acromialis, M. pectoralis major, M. trapezius transversalis., M. trapezius descendens., M. latissimus dorsi, M. serratus anterior, M. teres major, M. tricepis lateralis., M. extensor carpiulnaris, M. policis brevis. The use of the 29" racket shows in all cases the lowest values for the EMG integrals. The comparison of the means regarding the on- times of the muscles shows a comparable result. The on- times using the 29" racket are lower in all significant differences. In all cases of significant differences the use of the 32" racket shows an earlier maximum mean (0.015 sec – 0.05 sec) of the highest EMG activity. Differences could not be found between the 29" racket and the 27" racket.

The results show that an extension of rackets does not generally cause increased stress in players. Differences can be shown. The promise that extended rackets lead to higher reachable ball velocities could be confirmed. But the advantage is not very great. Racket length seems not to be the most important parameter regarding players' stress, but rather what matters is probably other properties like the stiffness of the racket or the tension of the strings. The evaluation of the EMG must be discussed very differently: It could not be confirmed that extended rackets generally induce increased muscle activity.

LITERATURE:

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