Evaluating shoulder function among competitive tennis players based on kinematic analysis of circumduction tests and tennis serve.

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1. Introduction

The serve is the most important shot in tennis but it is also associated with the highest prevalence of injury (Chung and Lark 2017). In this context, the prevention of shoulder injuries during the serve in tennis appears fundamental. Numerous clinical or active motion tests are commonly used to evaluate shoulder mobility with the objective to propose a diagnosis and/or the prescription of additional medical imaging (Salamh and Lewis 2020). However, there are some limits to these tests. First, these tests are conducted when pain or at least complaints are expressed by the athletes. Secondly, there is a lack of consistency between these tests and the sport-specific movements performed by the athlete. Finally, it remains challenging to identify relevant and repeatable clinical tests of the. 3D-kinematics analysis is already used to accurately analyze numerous sport-specific movements in sport (golf, football, gymnastics). Hence, the combination of 3D-movement analysis with active motion clinical tests seems to be an interesting option to evaluate the shoulder function of tennis players and to explore some individualized biomechanical determinants in relation with the risk of injury (maximum joint amplitude, muscle length, co-activation, etc.). Circumduction movement seems to be the most adequate according to the scientific literature (Haering et al. 2014). The main objective of this study was to propose a 3D-kinematics analysis of an active movement test (AMT) based on arm circumduction that explores shoulder mobility among tennis players and to investigate the reliability of this test. To that end, we first measured the repeatability of the test using the Intraclass Correlation Coefficient (ICC). Secondly, we analyzed whether the proposed test encompasses the maximum joint ranges of motion (ROM) observed during the tennis serve.

2. Methods

2.1 Participants

Fifteen tennis players (mass: 79.2 ± 8.3 kg; height: 1.79 ± 0.10 m; age: 27.4 ± 9.3 years) have given their written consent to take part in this study. They had not experienced any injury in the past six months and felt no discomfort on the shoulder at the date of the experimentation.

2.2 Protocol

After carrying out their own warm-up routine, the participants were asked to perform a sequence of 12 active circumduction motions without racquet to explore the shoulder function. Participants also had to hit 10 flats first serves with their personal racquet. The sequence was composed of 4 starting positions (Figure 1) (dominant arm at 45° (1), 90° (2), 135° (3) and 180° (4) from the mediolateral axis of the body), with an arm elevation of 90° and the upper limb fully extended. For each starting position, the movement was repeated 3 times, once with each position of rotation: neutral rotation (a), internal rotation (b) and external rotation (c) (Figure 1). The subjects had to produce a large back and forth circumduction in the plane of elevation defined by the starting position (Haering et al. 2014). There were no time or speed constraints but the subjects were asked to reach their articular limits and to keep their head and chest as straight as possible during the whole sequence. In order to study the repeatability of the test, the sequence was done 4 times per subject with a 1-min rest between each. The order of the starting positions and the order of arm rotations were randomized for each subject but were the same for the 4 repetitions of the sequence.

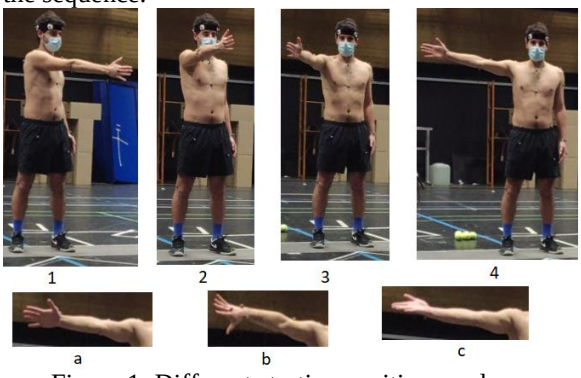


Figure 1: Different starting positions and arm rotations during the test

2.3 Data collection

The subjects were equipped with a full-body set of 43 markers (Martin 2013). 3D-kinematical data were collected using an optoelectronic system composed of 21 infrared cameras Qualisys Oqus 700+® (Qualisys, Göteborg, Sweden) recording at a frequency of 300hz. The 3D markers' locations were reconstructed

in the Qualisys Track Manager® software. The data have been processed and analyzed with Matlab® (MathWorks, Portola Valley, California, USA). The CusToM toolbox was used for the 3D-kinematics process (Muller et al. 2019). ROM of thoraco-humeral angles were extracted for each degree of freedom using ISB recommended sequence (plan of elevation, elevation and axial rotation) and ratio between external and internal rotation was calculated. ICC was calculated between the 4 repetitions of the subjects.

3. Results and discussion

Table 1 shows the amplitudes for the elevation (EL), axial rotation (AROT) axes and the ratio between external and internal rotation. Data on plan of elevation (PEL) are not showed due to a high variability caused by gimbal lock problems. For each of these variables, ICC between the 4 trials was calculated as well as the means for the AMT and the serves. The percentage of how much the serves are encompassed by the AMT was also estimated.

	Ampl EL	**Ampl AROT**	**Ratio AROT ext / AROT int**
ICC	0.89	0.88	0.93
p-value	<0.01	0.02	<0.01
Mean AMT (°)	108.1 ± 13.8	157.1 ± 22.4	1.70 ± 0.91
Mean Serve (°)	74.5 ± 16.1	147.4 ± 27.3	1.76 ± 0.71
Encompassment (%)	68.9	93.8	/

Table 1: ICC and p-value (for ICC=0.75), mean of amplitude during AMT and serve and encompassment (%) of serve over AMT for the elevation (EL) and rotation (ROT) axes and for the ratio between external and internal rotation.

Based on these results, ICC showed good to excellent repeatability. Hence, for clinical evaluation, only one repetition could be required to measure the maximal ROM that a player can reach. Furthermore, results showed that serve amplitudes represent 69% of the AMT for elevation axis and 94% for the rotation axis which means that players are closer to their limits on this axis. This result was expected as shoulder internal rotation is the main contributor for the velocity of the ball (Elliott 2006) but is also involved in a large number of injuries among tennis players (Chung and Lark 2017).

A compromise in the shoulder's rotational motion is essential and reinforces the need to be able to assess it accurately and longitudinally. This methodology proposes a combined assessment of shoulder function and mobility during serve leading to a repeatable, and individualized evaluation of shoulder function.

These findings could contribute to assist medical practitioners, sport physicians and physiotherapists to design efficient programs for diagnosis, management and prevention of shoulder injuries. In this sense, the perspectives are to develop a visual user-friendly tool that overlays the individual kinematics of the server with its threshold values during the active motion test.

4. Conclusions

The main finding of this study suggests that this active movement circumduction test is relevant and accurate to measure the active shoulder ROM of tennis players. The comparison between this test and actual serves can help to individualize threshold for a strategy of injury prevention. Further studies are in progress to create a more solid database.

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References

Chung KC, Lark ME. 2017. Upper Extremity Injuries in Tennis Players: Diagnosis, Treatment, and Management. Hand Clin. 33(1):175–186. https://doi.org/10.1016/j.hcl.2016.08.009

Elliott B. 2006. Biomechanics and tennis. British Journal of Sports Medicine. 40(5):392–396. https://doi.org/10.1136/bjsm.2005.023150

Muller A, Pontonnier C, Puchaud P, Dumont G. 2019. CusToM: a Matlab toolbox for musculoskeletal simulation. JOSS. 4(33):927. https://doi.org/10.21105/joss.00927

Salamh P, Lewis J. 2020. It Is Time to Put Special Tests for Rotator Cuff–Related Shoulder Pain out to Pasture. J Orthop Sports Phys Ther. 50(5):222–225. https://doi.org/10.2519/jospt.2020.0606

Haering D, Raison M, Begon M. 2014. Measurement and Description of Three-Dimensional Shoulder Range of Motion With Degrees of Freedom Interactions. Journal of Biomechanical Engineering https://doi.org/10.1115/1.4027665

Martin C. 2013. Analyse biomécanique du service au tennis: lien avec la performance et les pathologies du membre supérieur. :187.

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