WHEELCHAIR TENNIS: A PRELIMINARY KINEMATIC ANALYSIS OF THE UPPER LIMB DURING SERVE

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SUMMARY
To investigate the causes of the overuse shoulder joint injury, the tennis serve of a wheelchair tennis player was analysed twice, before and after a period of training, and compared with that of an able-bodied tennis player. A validated specific protocol of the upper limbs was applied using stereophotogrammetry. The protocol adopted allowed to distinguish differences in the girdle joint that were not previously analysed. After the period of intense training, the girdle joint showed values more similar to the AP and the glenohumeral joint showed lower range of motion. Especially the reduction in the internal-external rotation of the glenohumeral joint showed a more controlled motion that can reduce the risk of injury.

INTRODUCTION
Up to 78% of wheelchair users, athletes and non-athletes, report shoulder pain [1]. The most commonly found pathology are rotator cuff impingement, glenohumeral instability, and biceps tendonitis [1]. The weight-bearing role of the shoulder is thought to be one cause as this joint was designed for mobility rather than for stability [2]. Wheelchair athletes, in addition, put increased load and repetitive stress through their shoulders during sporting activities. Muscle imbalances have also been shown to be a factor in impingement syndrome in wheelchair athletes [3].

An accurate and quantitative biomechanical analysis of the athletes during the execution of the specific sport exercises is the only way to understand the causes of this overuse injury. This type of analysis has been performed extensively on able-bodied tennis players (APs) and weakly on wheelchair tennis players (WPs). Only a recent study examined the specific kinematic and kinetic analysis of wheelchair tennis serve [4]. As WPs and APs experienced similar pre and post-impact shoulder joint loads, shoulder joint injury risks appear similar [4]. However, the protocol adopted did not consider all the degrees of freedom of the shoulder joint.

The aim of the present study was to better understand the causes of the shoulder joint overuse injury in WPs, using a validated specific protocol of the upper limbs [5]. The tennis serve of a WP first and after a period of intense training and international competitions was analysed.

METHODS
2.1 Athlete and task description
A Caucasian Italian right-handed athlete was analysed. The subject was a WP and suffered from a complete L1 spinal cord injury, with no pathologies at the shoulder. The subject was acquired twice: the first time was 31st in the world ranking (WP1) and the second time, after a period of 15 months of intense training and international competitions, was 25th (WP2).

Two repetitions of the 9 combinations among 3 serve types were acquired each time: first and second, lateral and central, and from the deuce and the advanced service box. The kinematics of both acquisitions were compared with that of an AP previously acquired [6].

2.2 Kinematic analysis
From the biomechanical viewpoint, the racket arm was modelled as an open kinematic chain formed by 4 segments (thorax, shoulder girdle, humerus and forearm), with 7 degrees of freedom: 2 describing the mobility of the shoulder girdle [7], 3 of the glenohumeral joint, and 2 of the elbow. The thorax and the proximal humerus bone embedded systems of reference were defined following the ISG recommendations [8]: H1 for the humerus, with z axis pointing backward. For the girdle, the x axis was assumed from IJ to GH, the z as the cross product of x and the y axis of the thorax, and the y consequently. Using appropriate sequences of Euler angles, the relative orientation of adjacent segments were computed, obtaining the following joint angles: protraction-retraction and elevation-depression for the shoulder girdle, flex-extension, ab-adduction and internal-external rotation for the glenohumeral, flex-extension, carrying angle and pronosupination for the elbow. The thorax orientation was calculated with respect to the orientation of the thorax in the static position of the athlete, at the beginning of each trial. In order to track the segment poses during motion, a stereophotogrammetric system (Smart-D, BTS, 10 cameras, 250Hz) was used. 5 markers were placed on the thorax anatomical landmarks, 5 on the humerus, and 4 on the forearm to form technical clusters (fig 1). Anatomical calibrations were then performed as described in [5].

Figure 1: Experimental markers set-up.

All kinematic data were processed using the BTS SmartAnalyzer software. Thus, the following phases, reflecting meaningful temporal or kinematic characteristics of the serve,
were identified: cocking (from the backswing racket’s highest point (BHP) to maximum external rotation of the glenohumeral joint (MER)) and forward-swing (from MER to the racket ball pre-impact (IMP)) [4].

RESULTS AND DISCUSSION
The results of different levels of training (WP1 and WP2) were first analysed. No significant differences of girdle, glenohumeral and elbow kinematics were found among serve types in both acquisitions.

The girdle joint showed clearly a different pattern of movement particularly for the elevation-depression degree of freedom (fig 2). At the time of the second acquisition, during the cocking phase, the girdle was less retracted and more elevated with respect to the first acquisition. In detail, at the BHP, the girdle of WP1 was more retracted (-32.6±5.1°) than the girdle of WP2 (-25.4±1.9°). The girdle of WP1 was more depressed during the cocking phase, reaching a minimum of -11.1±4.2°. This difference increased and only at the MER the subjects exhibited more similar values. At the IMP, the girdle joint was elevated 16.1±8.9° and 20.5±1.5° for WP1 and WP2, respectively. The patterns and the values of the girdle joint in the second acquisition were more similar to those of the AP [6].

As for the glenohumeral joint(fig 3), similar pattern with a lower range of motion in the serve were found in all three degrees of freedom for the second acquisition with respect to the first one. The different timing of the MER with respect to the AP was confirmed also in the second acquisition [6]. On the contrary, differently from the first acquisition, the MER showed lower values (80.8±5.0°) with respect to the WP1 and AP (100.5±5.2° and 103.5±3.9°, respectively).

In the elbow joint, no significant differences between the two acquisitions were found.

The kinematics of the two acquisitions, WP1 and WP2, was secondly compared with AP kinematics. The WP showed similar patterns for the glenohumeral and the elbow joint only during the forward-swing with respect to APs. On the contrary, the patterns of the shoulder girdle were different during the entire serve. After the period of intense training and several international competitions, the girdle joint showed values more similar to the APs and the glenohumeral joint showed lower range of motion.

CONCLUSIONS
The differences in the cocking phase and in the timing between the WP and the AP can be justified by the limited trunk range of motion and the constrained position on the wheelchair. The protocol adopted allowed to distinguish differences in the girdle joint that were not previously analysed. The reduction in the range of motion at the glenohumeral joint, particularly in the internal-external rotation, showed a more controlled motion that can reduce the risk of injury. Anyway, the typical WPs shoulder pain could be related to the kinematics differences with respect to APs. However, to support these hypotheses, further kinematics and kinetics analysis will be performed on a larger number of players.

REFERENCES
5. Stagni, R. et al., Kinematic analysis techniques and their application in biomechanics, 2008