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# Impact of holding a racket on upper limbs kinematics for para-badminton: a preliminary study

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## 1. Introduction

Wheelchair badminton was only introduced in the Paralympic scene during the Tokyo Games in 2021. Two classes are defined for this sport: WH1, who are athletes with little or no abdominal function, and WH2, who have abdominal function. The specificity of this sport, in term of movement, resides in the fact that athletes constantly performs back and forth motions with a racket in their hand.

The propulsion is then made difficult because of the contact with the handrim which is no longer made with the hand but through the racket. It has already been shown that holding the racket lowered propulsion effectiveness and increased the risk of injury by modifying the way the force is applied to the handrim (Alberca et al. 2022). In para-tennis, it has also been shown that holding a racket lowered the push time, and increased the power loss during propulsion (de Groot et al. 2017). The trunk flexion was also impacted by the racket grip (de Groot et al. 2017) which could lead to differences in upper limbs kinematics, and in temporal characteristics of propulsion, even without a racket (Sanderson and Sommer 1985). The impact of holding a racket on the upper limbs has not been studied for para-badminton, it could then be interesting to study the differences of the upper limbs kinematics of the para-badminton athletes when holding a racket.

Therefore, the aim of this study was to analyze the kinematics of the upper limbs during two types of propulsion: with and without the racket. It has been hypothesized that, since the trunk was impacted by the racket grip, the athlete belonging to the WH1 would compensate the lack of trunk mobility by increasing the range of motion of his upper limbs in comparison to the athlete belonging to WH2.

## 2. Methods

### 2.1 Participants

Two French elite para-badminton players volunteered for this study. One was competing in WH1 category ( $S_1$ ), while the other one competed in WH2 category ( $S_2$ ). The categories were defined according to the Badminton World Federation classification regulations. Their height and weight, ( $S_1$  and  $S_2$ ) were

1,68 m and 1,8 m, and 71 kg and 60 kg. Athletes used their own wheelchair designed for para-badminton, and their own racket. This research was authorized by EudraCT / IDRCB n° 2020-A02919-30.

### 2.2 Experimentation

Each athlete performed back and forth pushes over three meters during a minute under two conditions. The first one was without the racket (No Racket), and the second one with the racket in their hand (Racket). A total of 15 markers were placed on the scapula, forearm, arm, and hand on the side of the racket, according to (Wu and Cavanagh 1995) to perform a 3D-analysis of the kinematics of the upper limbs. Positions of the reflective markers were captured using a 22-cameras optoelectronic motion capture system (Vicon® System, ©Oxford Metrics Inc., UK) working at 200 Hz.

### 2.3 Data processing

The trajectories of the markers were smoothed using a sliding window average method over five frames. The OpenSim model with the scapulothoracic joint from Seth et al. (2016) was used. The joint angles were computed using the inverse kinematics tool of OpenSim 4.3 and filtered afterwards with a 2<sup>nd</sup> order Butterworth filter with a cutting frequency of 6 Hz.

The gleno-humeral elevation, elbow flexion, and wrist flexion have been computed for the different propulsions. The forward phase (FP) and backward phase (BP) have been manually identified when the athlete was changing direction. The range of motion of the elevation of the shoulder, the elbow flexion, and the wrist flexion was then reported for each phase. There was at least seven forward or backward phase for each acquisition, so the values were averaged over the seven first phases. The results of the upper limb on the side of the racket were reported. Given the low number of athletes, no statistical test was performed.

## 3. Results and discussion

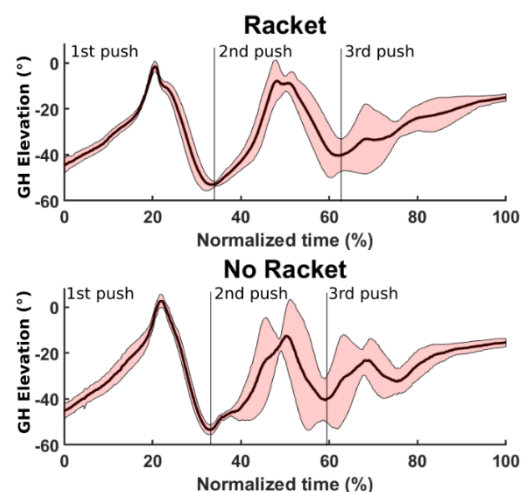


Figure 1 Mean (strong dark line) and standard deviation (red fill) of the evolution of the gleno-

humeral elevation during the seven forward propulsions for  $S_1$  with and without the racket. The gleno-humeral elevation pattern did not differ between the Racket and No Racket trials (figure 1), and so did the other coordinates. This might be due to the extensive training that both athletes had in their wheelchair, and their ability to propel themselves even with a racket in their hand. However, it was observed that the range of motion of gleno-humeral elevation was higher, in average, over the second push while holding onto the racket for  $S_1$  (figure 1). Overall, the range of motion of the upper limbs of  $S_2$  were higher than the one of  $S_1$  (table 1) for both FP and BP. Nevertheless, athletes had a higher range of elbow flexion and gleno-humeral elevation (except  $S_2$  without a racket) during FP than BP (table 1). The differences observed between FP and BP here were mostly due to the different technique used by athletes to propel forward or backward.

Range of motion		GH Elevation	Elbow Flexion	Wrist Flexion	
$S_1$	Racket	FP	50.9 ± 3.9	85.8 ± 8.0	61.8 ± 4.9
		BP	43.8 ± 2.8	72.3 ± 5.4	77.7 ± 2.0
	No Racket	FP	55.4 ± 3.9	91.2 ± 6.9	62.9 ± 6.8
		BP	47.9 ± 1.9	65.4 ± 3.7	76.6 ± 3.1
$S_2$	Racket	FP	57.5 ± 3.1	92.6 ± 6.2	76.6 ± 2.4
		BP	64.4 ± 2.8	81.2 ± 7.9	85.5 ± 5.8
	No Racket	FP	59.9 ± 3.7	98.8 ± 5.5	72.8 ± 8.1
		BP	57.7 ± 2.1	87.8 ± 7.5	76.1 ± 18.3

Table 1. Amplitude (mean ± std) of the studied angles for both subjects with the two conditions. FP is forward phase and BP is backward phase.

However, there were differences between both activities. Indeed, for  $S_1$ , the range of motion of the gleno-humeral elevation was lower when holding a racket both for FP and BP. However, it was higher for  $S_2$  for BP. The range of motion of the gleno-humeral elevation of  $S_1$  was higher during the No Racket activity for both FP and BP but it was higher during BP and lower during FP during the No Racket activity for  $S_2$ .

The wrist of  $S_1$  was the least impacted joint, with less than 1° in average of difference in range of motion between the two activities.  $S_2$  had a higher wrist range of motion but a lower elbow range of motion during the Racket activity whereas  $S_1$  had a higher elbow range of motion during BP and lower during FP.

The compensation in terms of range of motion of the upper limbs differed between both subjects. And the pattern of compensation was not the same during FP and BP, meaning that athletes had their own strategy to compensate the lack of grip on the handrim with their upper limbs.

#### 4. Conclusions

This preliminary study was the first to investigate the impact of holding a racket on upper limbs kinematics during propulsion in para-badminton.

Differences have been found between the FP and BP which could be due to the different technique used to propel forward or backward. The differences due to holding the racket were however specific to each athlete.

Those results need to be confirmed on more athletes, to identify if the discrepancies come from the techniques used or from the differences in term of handicap, between athletes belonging to WH1 and WH2. Biomechanical analysis could then be useful to help classify athletes based on their mobilities.

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