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# Assessment of the arm 3D angular velocity during arm elevation, in people with subacromial pain syndrome and asymptomatic people: a proof of concept study

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## 1. Introduction

Assessing shoulder movement performance is a need and a challenge for clinicians. There is no clear definition of shoulder performance. Inertial Measurement Units (IMU) give clinicians an easy access to temporal parameters. Subacromial pain syndrome (SPS) is the most frequent shoulder pathology. SPS is associated with activity limitation and decreased quality of life. Arm velocity was assessed in people with stroke during functional tasks (Alt Murphy 2018). Temporal parameters from IMU had already been used to assess shoulder performance. One study used cumulative velocity distribution to assess arm movement in the daily routine before and after shoulder surgery in people with SPS (Duc 2013). The current proof of concept study aims to assess the velocity of the symptomatic arm in people with unilateral SPS compared to the contralateral arm and to asymptomatic participants during shoulder maximal active arm elevations performed at spontaneous velocity. We hypothesized that the mean velocity will be lower in the symptomatic arm than the contralateral arm in participants with SPS and then the arms in asymptomatic participants (control group).

## 2. Methods

We performed a single-center prospective proof of concept study. All participants had been informed and agreed that their personal data could be used for research purposes including scientific publication (CER AP-HP. Centre Université Paris Cité, Reference: 2023-06-01 and General Data Protection Regulation of APHP (N° 2025 0321160410).

Each subject was instrumented with 8 Mtw Awinda XSens® sensors attached on the head, thorax, scapula, humerus, and forearms using reference points (Cutti 2008) with a sampling frequency of 100Hz. The resting position (arm straight along the body, thumb pointing forward) was used to define a subject frame (x-axis orthogonal to the frontal plane pointing forward and z-axis upward and vertical). Only data from the forearms (to define the subject frame) and the humerus were used in the current study. After training, the participant performed 2 successive trials of bilateral arm elevation in the sagittal (AEBPSA), then the scapular (AEBPSC) and the frontal (AEBPF) plane in a seated position. Then the participant performed 2 unilateral arm elevations in the sagittal plane (DUPSA) in a standing position. All arm elevations were performed

**Table 1.** Mean velocity, velocity variation and velocity ratio between both arms of the two groups.

Arm elevation	Parameters Mean (SD)	SPS		p-value	Control	p-value
		Sympt	Asympt			
AEBPSA $n_{SPS} = 8$ $n_c = 11$	$\bar{\omega}$ (°/s)	26.2 (14.9)	26.4(11.9)	0.383	40.5 (7.6)	<b>0.035</b>
	$\Delta$	16.7 (6.5)	15.5 (5.6)	0.250	7.6 (2.2)	<b>0.002</b>
	$R$ (%)	13.7 (10.8)			7.7 (9.0)	0.109
AEBPSC $n_{SPS} = 8$ $n_c = 11$	$\bar{\omega}$ (°/s)	24.0 (9.7)	24.9 (8.0)	0.461	37.6 (10.0)	<b>0.003</b>
	$\Delta$	15.7 (7.9)	13.6 (4.0)	0.461	8.3 (3.6)	<b>0.006</b>
	$R$ (%)	9.1 (9.6)			4.6 (4.1)	0.238
AEBPF $n_{SPS} = 8$ $n_c = 11$	$\bar{\omega}$ (°/s)	27.6 (11.5)	31.1(12.9)	0.055	48.3 (15.8)	<b>0.002</b>
	$\Delta$	27.6 (32.4)	21.9(22.3)	0.078	9.3 (3.5)	<b>0.004</b>
	$R$ (%)	13.2 (13.2)			10.7 (12.3)	0.395
DUPSA $n_{SPS} = 7$ $n_c = 11$	$\bar{\omega}$ (°/s)	31.9 (14.4)	40.6(13.6)	0.375	51.0 (14.3)	<b>0.013</b>
	$\Delta$	11.6 (4.8)	11.1 (3.5)	0.813	7.1 (2.3)	<b>0.018</b>
	$R$ (%)	29.0 (18.8)			11.2 (12.0)	<b>0.027</b>

AEBPSA; AEBPSC; AEBPF: bilateral elevation in the sagittal, scapular, frontal plane, respectively; DUPSA: unilateral elevation in the sagittal plane;  $n_{SPS}$ : number of participants with SPS;  $n_c$ : number of participants in the control group; Sympt: symptomatic; Asympt: asymptomatic;  $\bar{\omega}$ : mean arm spontaneous velocity;  $\Delta$ : velocity variation (dimensionless);  $R$ : velocity ratio between both arms of the same group; in bold  $p < 0.05$ .

at a free velocity. The participant had 3 seconds of rest between the two arm elevation trials. Considering the excellent test-retest reliability that we measured on the maximal arm elevation (all ICC  $\geq 0.9$ ), we selected only data from the second elevation for velocity analysis (the first trial was considered as a familiarization trial). All the arms of the participants in the control group were computed as a control template.

The gyroscope data without any post-treatment filter were used to calculate the mean norm angular (3D) velocity in degrees per second ( $\bar{\omega}$ ) (1), the velocity variation ( $\Delta$ ) (2) during movement time and the ratio ( $R$ ) of  $\omega$  between two arms (that assessed the difference between arms); asymptomatic (SPS) or dominant (control) arm as reference (3).

$$\bar{\omega} = \text{mean} \left( \sqrt{\omega_{i_x}^2 + \omega_{i_y}^2 + \omega_{i_z}^2} \right), i \in [1, \text{length}(\omega)] \quad (1)$$

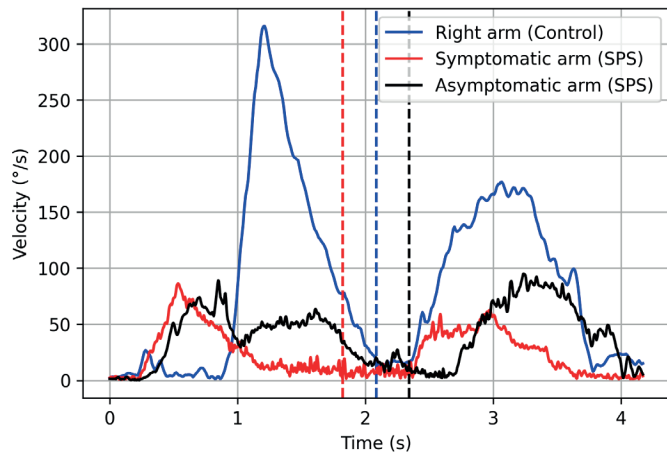
$$\Delta = \frac{\sum |\omega_{i+1} - \omega_i|}{\max(\omega) - \min(\omega)}, i \in [0, \text{length}(\omega) - 1] \quad (2)$$

$$R(\bar{\omega}) = \frac{|\bar{\omega}_{\text{reference}} - \bar{\omega}|}{\bar{\omega}_{\text{reference}}} * 100 \quad (3)$$

The paired Wilcoxon was used to compare both participant's arms in the SPS group and the unpaired two-sample Wilcoxon test was used to compare the symptomatic arm of the SPS group and the arms in the control group using, ( $p < 0.05$ ) (Python 3.9.21; Pingouin 0.5.5).

### 3. Results and discussion

We included 8 participants planned for rehabilitation with unilateral SPS [female: 5/8 (62.5%); Mean (SD): age: 54 (12) years; BMI: 26.4 (4.4), pain intensity: 50 (20); symptom duration 30 (26) months; activity limitation (QuickDash 0-100): 47.7 (27.5)] and 11 age matched asymptomatic participants (control group) [female: 7/11 (64%), Mean (SD): age: 56 (5), BMI: 24.30 (4.35)], all were right-handed. (Table 1, Fig. 1). For all arm elevations, the norm angular velocity was significantly lower (all  $p \leq 0.035$ ) and the velocity variation was significantly higher ( $p \leq 0.018$ ) in the symptomatic arm in the SPS group than in the control group. For all movement the ratio was quantitatively higher in the SPS group compared to the control group (significant difference for unilateral elevations,  $p \leq 0.027$ ).



**Figure 1.** Spontaneous arm velocity curves of the symptomatic arm (red), asymptomatic arm (black) of a participant with SPS, and the right arm (blue) of participant from the control group (same age) during DUPSA. Dashed lines represent maximal arm elevation.

The results are partially in concordance with our hypotheses. The mean norm angular velocity was lower and the velocity variation was higher in the symptomatic arms in the SPS group than in the control group. The absence of significant differences of the mean velocity between both arms in the SPS group may be related to a neuromotor effect that induces symmetrical movements (Li 2005). It may also highlight a bilateral impact of the syndrome (Navarro-Ledesma 2022).

#### 4. Conclusions

Our results show that mean norm angular velocity and the velocity variation differed in the symptomatic arms in the SPS group compared to the control group. The 3D velocity related parameters seem to be relevant to assess arm performance in people with SPS. Future study should assess the velocity parameters' change after rehabilitation and their correlation with activity limitation in participants with shoulder disorders.

#### Conflict of Interest Statement

The authors have no relevant conflicts of interest.

#### Contributor Role

Conceptualization: AR, QL, MMLC, JB, Data collection: JB, CE. Formal analysis: CE, AR, NM, Methodology: AR, FP, MMLC, Supervision AR, NM, MMLC, CN, FR Validation: AR, MMLC, NM, CN,

FR Writing- original draft: CE, AR Writing- review & editing CE, QL, JB, FP, NM, MMLC, CN, FR, AR.

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