# INERTIA SENSOR BASED MOTION TEST OF THE SHOULDER FOR CLINICAL DIAGNOSTICS

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## INTRODUCTION

In clinical orthopaedics outcome measures using patient or clinician based questionnaires suffer from a ceiling effect, subjectivity and the dominance of pain over function. Rising patient demands cannot be measured appropriately. For the DASH score used in shoulder assessment it was even shown that it correlates more with the function of the healthy than the affected side[1]. Motion analysis with opto-electronic systems, force plates or EMG is a powerful research tool but lab-based, too expensive and time consuming for routine clinical application. Inertia sensor based motion analysis (IMA) can produce objective motion parameters while being faster, cheaper and easier to operate. For the diagnostics of knee pathologies a gait test has been validated[2]. For the shoulder a sway parameter could distinguish healthy from pathological subjects in a small group[3].

In this study, a.) a simplified shoulder test and a clinically more lucid score is defined, b.) a reference database for healthy shoulder motion is created and the effects of demographics, training or fatigue are studied and c.) the score is validated against gold standard clinical scores.

## METHODS

An inertia sensor *(Inertia-Link-2400-SK1, 41x63x24mm$^3$, 39g)* comprising a triaxial accelerometer (±5g) and a triaxial gyroscope (±300º/sec) was fixed by an adhesive patch on the humerus in standardized position.

Sixty two healthy subject (39.6 ±16.6yrs) without shoulder complaints and 16 subjects (54.4 ±12.7yrs) with unilateral shoulder pathology confirmed by x-rays or ultrasound (9 rotator cuff pathology, 5 subacromial impingement, 2 subcapital humeral fractures (2yrs post-op) were measured.

Two tests ('hand behind the head' and 'hand to the back') based on the Simple Shoulder Test (SST) were carried out for both shoulders with subjects sitting with an unsupported back and a neutral humeral and forearm position. Each movement was repeated three times at a self selected speed.

Based on a previous report[3], the motion parameters were defined by calculating the surface area described by combing two angular rates of independent axes (ARS) or by combing the angular rate and the acceleration of a single axis (Composite score). The relative asymmetry between two sides is scored.

**Fig. 1:** Test & sensor.

The shoulder scores were correlated with age, gender, height, weight, BMI and arm length (Pearson's R). Groups (e.g. healthy vs pathological) were compared using the student t-test. Diagnostic sensitivity and specificity to detect pathological shoulders were calculated. The scores were correlated to std. clinical scores (DASH, SST) for validation.

## RESULTS AND DISCUSSION

Healthy subjects showed a mean asymmetry of 10% (ARS) and 15% (Comp, Table 1). Confirming previous authors[3], the dominant and non-dominant side could not be distinguished ($p>0.9$). No demographic effects on the shoulder score were found ($r^2<0.07$), which seems to contradict the age related degradation of motion found with IMA for gait[2]. However, gait involves weight bearing joints which degrade faster than the non-weight bearing shoulder.

| Subjects | Score | N= | Asymmetry [%] | | |
|---|---|---|---|---|---|
| **Healthy** | ARS | 62 | **10.1** | *±7.6* | (0.19-28.4) |
| **Healthy** | Composite | 62 | **14.7** | *±10.9* | (0.15-44.7) |
| **Pathological**. | ARS | 16 | **38.3** | *±15.5* | (15.4-61.5) * |
| **Pathological** | Composite | 16 | **48.0** | *±16.5* | (23.1-79.5) * |

**Table 1:** Asymmetry healthy vs pathological (* $p<0.01$).

Subjects with shoulder complaints showed 3-4× higher asymmetry (ARS: 38%, Composite: 48%) than the healthy controls ($p<0.01$, Table 1). Based on thresholds (e.g. ARS: 19%) high diagnostic power was achieved (Table 2). Both scores were strongly correlated ($r^2=0.75$, Fig. 2). Due to this redundancy a single score is sufficient and the ARS score may be preferred in practice relying on rotations only.

| Score | Threshold | Sensitivity | Specificity |
|---|---|---|---|
| **Ang Rate (ARS)** | **19%** | **87.5** (60.4 - 97.8) | **85.5** (73.7 - 92.7 ) |
| **Composite** | **31%** | **87.5** (60.4 - 97.8) | **92.0** (81.5 - 97.0) |

**Table 2:** Diagnostic power to detect pathology (±95% CI).

The asymmetry between the healthy shoulders of both groups was the same ($p>0.18$) so that diagnosis can be based on comparison to the reference database instead of having to measure the healthy side in each subject halving test time. Diagnostic power went down only slightly (Table 2).

Motion scores and the clinical questionnaires (DASH. SST) were correlated ($p<0.05$) but only weakly ($r^2<0.30$). This indicates that while measuring the same phenomenon they capture different functional aspects of shoulder capacity. As the three repetitions produced similar results, no effect of training or fatigue could be found in both groups ($p>0.05$).

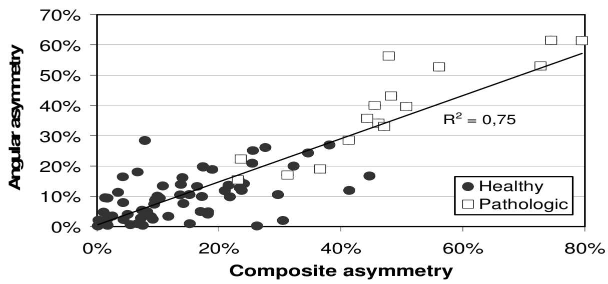


**Fig 2**: Correlation between the ARS and the Comp. score.

## CONCLUSIONS

The IMA shoulder test and asymmetry score can reliably distinguish healthy from pathological motion in simple ADL tasks and provide diagnostic power at clinically usable level. Test and analysis time are short and can be even shorter as only one arm, one parameter and a single repetition needs to be tested. Routine clinical application by non-specialist personnel is feasible. The IMA shoulder test adds objective information on functional capacity to the clinical scores.

## REFERENCES

1. Grimm et al. *Proc AAOS 2007*, #402
2. Senden et al. *Proc EORS 2008*, #O-074
3. Coley B, et al. *Gait & Posture* **25**: 523-532