Effect of Arm Deweighting using End-effector based Robotic Devices on Muscle Activity

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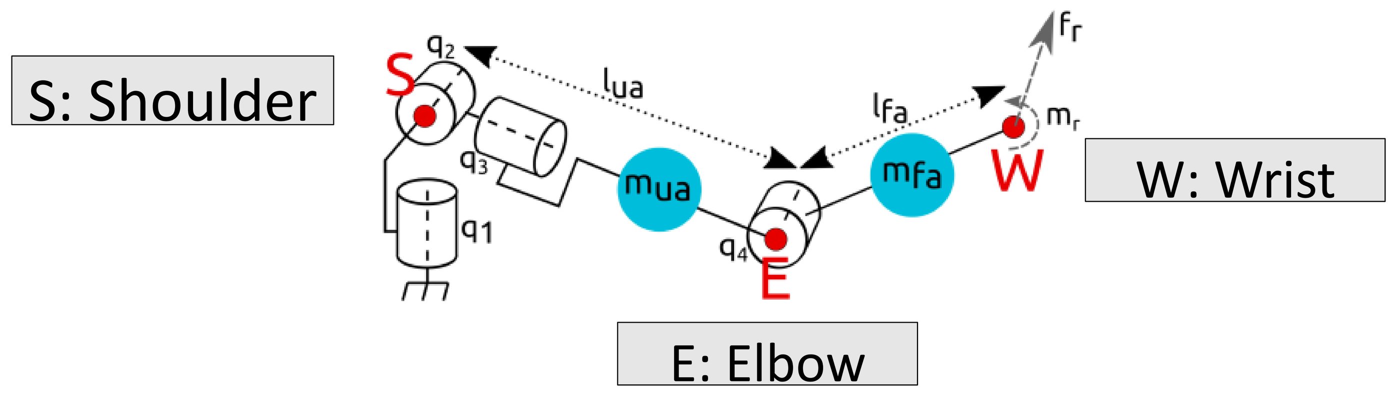
Background

Deweighting of the limb is often performed during rehabilitation exercises after brain injuries, as it allows patients with limited muscle activities to realise movements. Robotic devices have been developed to assist in providing the quantity of rehabilitation exercise required for recovery. A previously-published work [1] derives a deweighting algorithm for an end-effector based device which minimises the torques required to be generated by the muscles at each physiological joint, based on a 4 degree of freedom, 2-link model of the arm:



This work assesses the effects of that deweighting algorithm on the muscle activity of healthy subjects.

Methods

- 5 healthy subjects participated in the experiment
- The subjects' postures were measured using magnetic sensors measuring orientation of the upper and forearms.
- Their muscle activity was measured using EMG sensors on 6 major muscle groups: the biceps brachii (BB), lateral triceps (LT), posterior deltoid (PD), anterior deltoid (AD), pectoralis major (PM) and upper trapezius (UT), and normalised by Maximum Voluntary Contraction
- The EMU robotic device [2] was used to implement the deweighting algorithm – which has 3 actuated degrees of freedom

Experiments measured muscle activity under two conditions:

- Static – subject asked to maintain 4 different postures
- Dynamic –subject asked to move from one posture to another

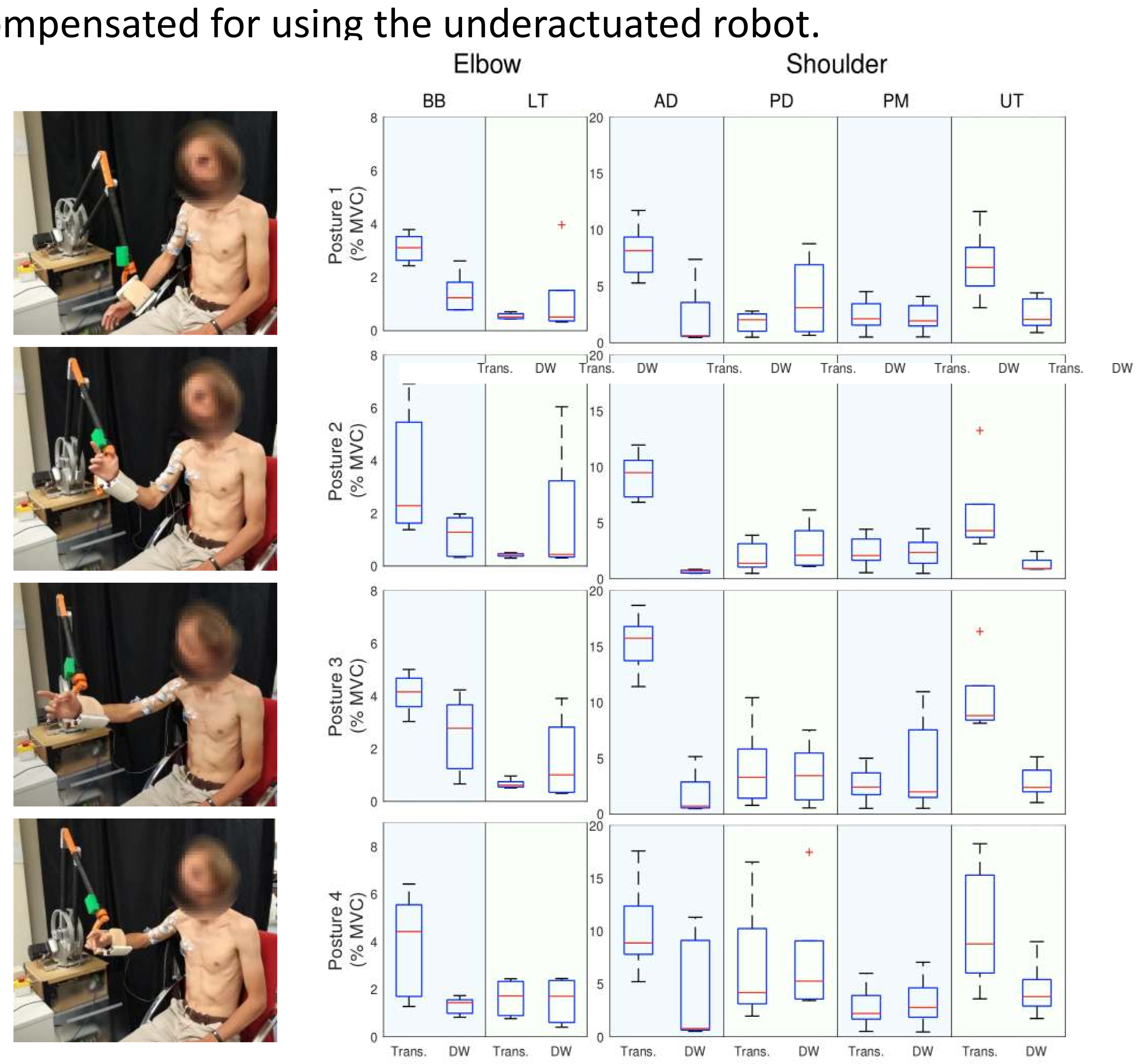
With the robotic device in two control modes:

- Transparent – where no force was applied to the subject
- Deweighting – where the deweighting algorithm was applied

Results

Static Condition

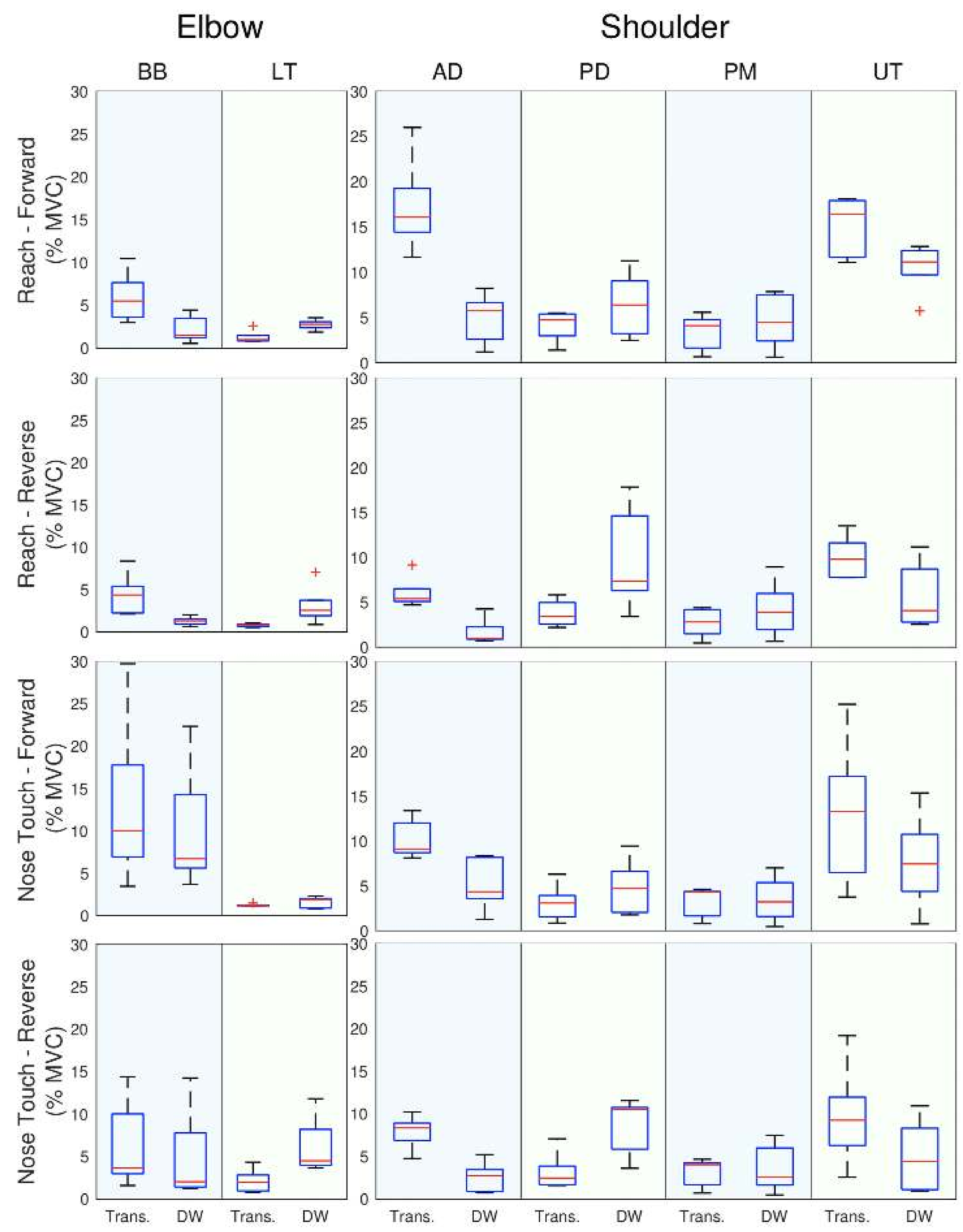
Four postures were tested. Postures 1-3 require progressively more joint torque as the shoulder is flexed and elbow is extended. Posture 4 includes a torque component which cannot be compensated for using the underactuated robot.



Dynamic Condition

Reach: Hand on knee *to* target placed at 80% of subject's maximum reach, directly forward and at shoulder height

Nose Touch: Hand on knee *to* nose.



Discussion

- Muscle activity decreased in static conditions, and movements against gravity, but increased in movements with gravity.
- The effect of the deweighting appears to be non-uniform across muscles and across different postures and movements.
- Changes in muscle recruitment patterns, both temporal and in magnitude, should also be considered to ensure correct movement recruitment patterns are regained.
- Further investigations are required to analyse the difference between local and distributed deweighting.

Conclusions

The work demonstrates the promise in the use of end-effector based devices to deweight patients arms in rehabilitation activities. However, the effects on muscle recruitment patterns should be considered further.

References

[1] Crocher et al, 2018, Upper-limb deweighting using underactuated end-effector based backdrivable manipulanda." IEEE Robotics and Automation Letters (RAL)

[2] Fong et al, 2017, EMU: A transparent 3D robotic manipulandum for upper-limb rehabilitation." International Conference on Rehabilitation Robotics (ICORR)

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