Automatically Modulating Activation of the Paralyzed Trunk and Hip Muscles to Improve Manual Wheelchair Propulsion

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OBJECTIVE

- During manual wheelchair (MWC) propulsion, the trunk flexes and extends throughout the propulsion cycle [1] to help create mechanical power for movement.
- MWC users with paralysis of core muscles assist/resist excessive forward or backward lean and stabilize the torso with their arms.
- Inefficient propulsion mechanics lead to shoulder problems and difficulty navigating challenging terrains.
- Constant activation of the paralyzed hip/trunk muscles with neural stimulation improves MWC propulsion efficiency on level terrain [2].
- Stimulation stiffens the torso so the arms can more effectively transmit forces and moments to the pushrim.
- Advantages disappear during sprints and up ramps.
- Appropriate timing of stimulation with the propulsion cycle may allow MWC users to better move or directionally stabilize their trunks [Figure 1] to increase efficiency and improve upper extremity mechanics.

DESIGN / METHOD

MWC propulsion consists of 2 main phases: contact when leaning forward with hands on the pushrims and recovery when pulling trunks and arms back to prepare for the next push [Figure 2].

We can detect transition periods between each phase by mapping the sagittal and frontal plane components [Figure 3] (using a custom wrist accelerometer [3]) to the propulsion phases (determined by an instrumented pushrim) [Figure 4].

RESULTS

Pushing with modulated stimulation:

- Rated “very easy” compared to “very difficult” without stimulation (7-point User Ratability Scale).
- Modulated stimulation increased propulsion speed on level ground (1.42 m/s vs 1.37 m/s without stimulation).
- With comparable pushing mechanics:
  - Peak force of 97.92 ± 14.02 N
  - 66.98 ± 5.93% mean fraction effective force
  - >95% of phase transitions were detected accurately by accelerometer (±2SD of those measured by instrumented pushrim).
- Initial data from 4 MWC users suggest a similar implementation is feasible and can be generalized [Table 1].

CONCLUSION

- Simple wireless wrist-worn accelerometers can:
  - Accurately, robustly detect phase transitions of MWC propulsion.
  - Provide effective command signals to control stimulation.
- Modulating trunk and hip activation to coincide with phases of the propulsion cycle can increased speed.

The purpose of this study was to determine a method to accurately detect transitions between contact and recovery phases of MWC propulsion with minimal instrumentation to appropriately modulate trunk stimulation for improved pushing mechanics during challenging conditions.

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