A comparison of methods to quantify control of the spine

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INTRODUCTION

- Low back pain (LBP) is associated with changes in trunk neuromuscular control [1].

Problem: Unknown if different movement control assessment techniques quantify similar performance outcomes.

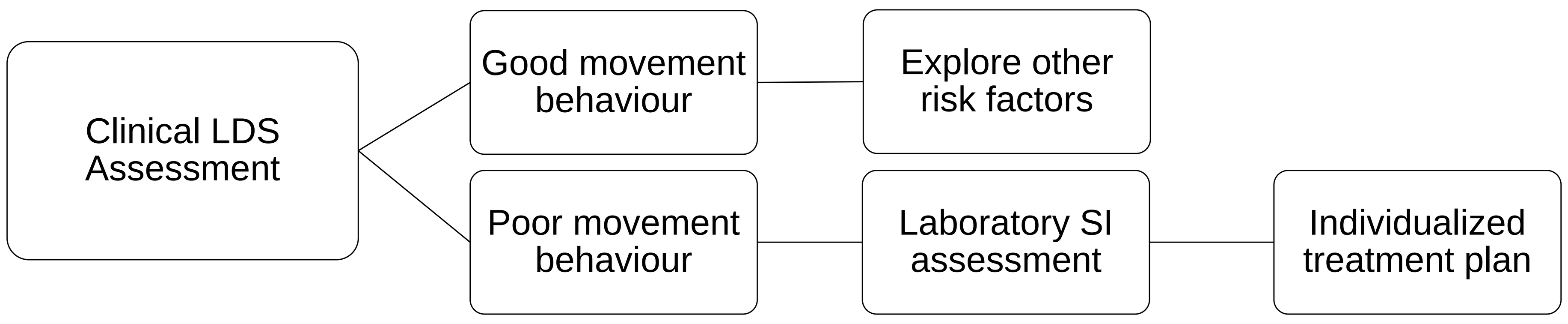
- Local dynamic stability (LDS) and systems identification (SI) are two methods commonly used to assess spine control (Table 1).
- It is important to understand the relationship between LDS and SI outcomes to improve overall spine movement control assessment.

Table 1. Advantages and limitations of LDS and SI in the assessment of spine movement control.

	Advantages	Limitations
LDS	• Dynamic tasks • Minimal equipment	• “black box” • Underlying causes unknown
SI	• Detailed insight into multiple subsystems	• Specialized equipment • Linear system assumption

- Methods could be used in concert to improve clinical assessment and treatment (figure 1).

Figure 1. Theoretical process from movement control detection to treatment planning.



Purpose: To understand the relationship between LDS and SI outcomes to implement efficient movement control assessment and more effective treatment plans.

METHODS

Participants

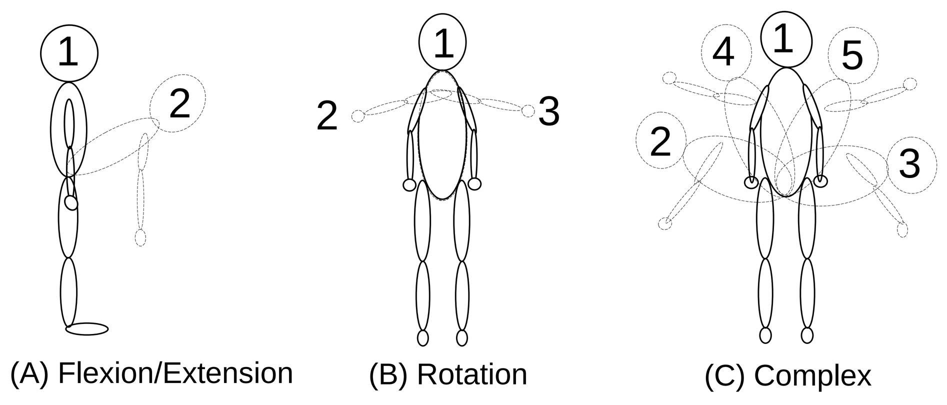
n	Age (years)	Height (m)	Mass (kg)
15	35 ± 12.5	1.75 ± 0.08	73 ± 11.6

Protocol

- Participants completed two tasks, LDS (figure 2) and SI (figure 3).

LDS

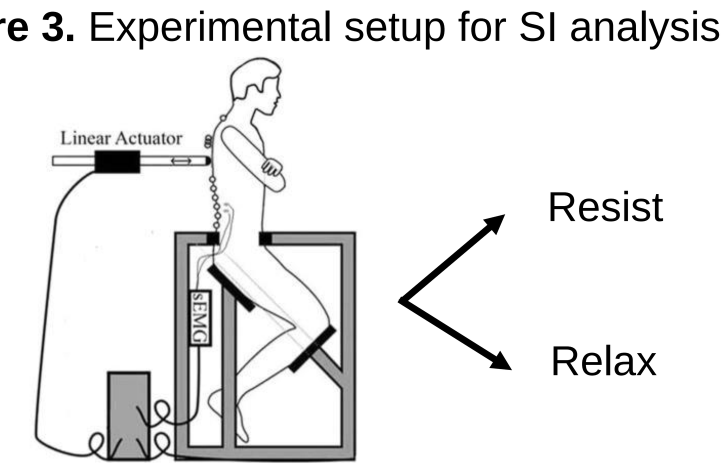
Figure 2. Movement tasks for LDS analysis



- 35 repeated movement cycles
- Motion capture data of trunk and pelvis collected.
- Maximum Lyapunov exponent (λ_{Max}) calculated using 6 and 12-dimensional state space techniques [2,3].

SI

Figure 3. Experimental setup for SI analysis



- Pseudorandom force perturbations applied to spine system.
- Admittance and reflex frequency response functions used to model lumbar stiffness (K), damping (B), muscle spindle position (K_p), velocity (K_v) and acceleration (K_a) feedback gains [4].

Statistical Analysis

- Stepwise linear regression used to build predictive model for λ_{Max} from SI outputs.

DV	IV					
λ_{Max}	Admittance < 1 Hz	K	B	K_p	K_v	K_a

- Adjusted R squared expressed as % of λ_{Max} variance described by Ivs.

RESULTS

6D Euclidean Norm

		SI Relax	SI Resist
λ_{Max}	Flexion/Extension	21.7%[a]	No significant Model
	Rotation	64.7%[b]	No significant Model
	Complex	No significant Model	No significant Model

a. Predictors: Admittance gain at 1.08 Hz
b. Predictors: Admittance gain at 0.22 and 0.73 Hz, K_p and K_v

12D Linear and Angular Velocities

		SI Relax	SI Resist
λ_{Max}	Flexion/Extension	No significant Model	No significant Model
	Rotation	36.5%[a]	21.6%[b]
	Complex	45.5%[c]	No significant Model

a. Predictors: Admittance gain at 1.08 Hz, K and K_a
b. Predictors: B
c. Predictors: Admittance gain at 0.73 Hz, K, B and K_a

DISCUSSION

Strong Predictors

- LDS assessment during repetitive rotations and SI assessment under relax task instructions capture similar movement control strategies.
- Both quantify a natural response to perturbations in similar upright postures.

Weak Predictors

- SI outcomes poorly predict 6D λ_{Max} values during a flexion/extension task and complex movement task.
- Large flexion/extension excursions may require different movement control strategies between tasks.

CONCLUSION

- Different predictive models between 6D and 12D λ_{Max} calculations enforce the importance of uniformly quantifying LDS.
- Similar motor behaviour is quantified by SI and LDS; however, only under specific task instructions.
- These methods capture different movement control strategies in many conditions.
- Development of a consistent framework for movement control assessment is integral to understanding how control of the spine is achieved.

Future Directions

- Explore relationship between LDS and SI outputs in LBP patients and other populations.
- Explore additional upright movement tasks to find optimal relationship between LDS and SI outputs. This will improve clinical LDS assessment of movement control and make detailed SI assessment more efficient.

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