Exploring Lifting Coordination in Chronic Low Back Pain Using Modified Vector Coding: A methodological Case-Based Approach

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INTRODUCTION

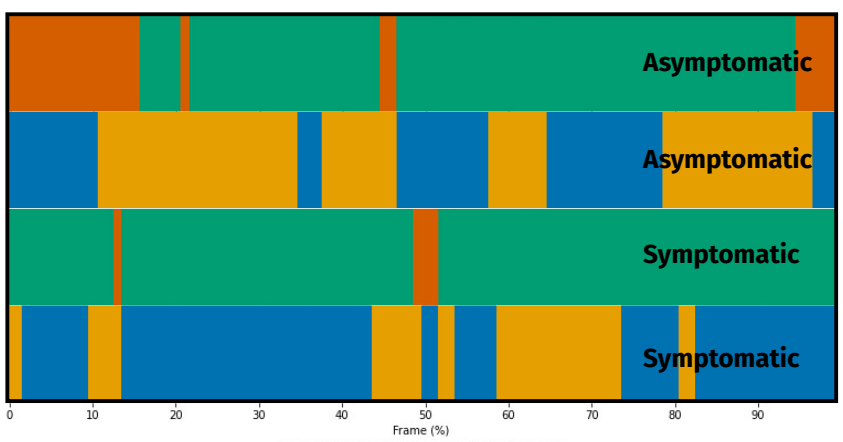
Modified vector coding (VC) has been used in biomechanics to analyze movement coordination and variability, including in populations with **low back pain (LBP)**. However, the application of this data analysis approach to lifting task remains limited and its potential to characterize coordination during lifting in LBP remains unclear[1]. **This work presents a methodological application of modified VC in lifting, using preliminary data from two individual cases.**

METHODOLOGY

A cross-sectional case-based study was conducted with **two female participants**: one with LBP (46 years, 1.56m, 70kg, pain intensity 5/10) and a healthy control (28 years, 1.70m, 60kg). Data were collected using a 13-camera system (Oqus 300, Qualisys AB, Sweden) at 200 Hz. Participants lifted a 2.9Kg box at preferred style; six trials were selected. Kinematic data were processed using Visual 3D (Has-Motion, Inc) and filtered with a generalized cross-validatory spline algorithm. Marker placement followed previously reported protocols[2], and a 9-segment model, with a segmented trunk, was optimized using segment optimization. **Coordination was analyzed in the sagittal plane using thorax-lumbar and lumbar-pelvis angles as oscillators.** Coupling angles and variability were computed using circular statistics[3]. VC analysis was performed using custom Python scripts (Spyder IDE). Angles were classified into coordination patterns: **in-phase proximal dominancy, in-phase distal dominancy, anti-phase proximal dominancy, and anti-phase distal dominancy**[3]. These describe the relative phase and contribution of proximal (thorax-lumbar) and distal (lumbar-pelvis) joint angles. In-phase patterns denote simultaneous directional change, while anti-phase indicates opposing movement. Dominancy reflects the joint contributing most to coordination.

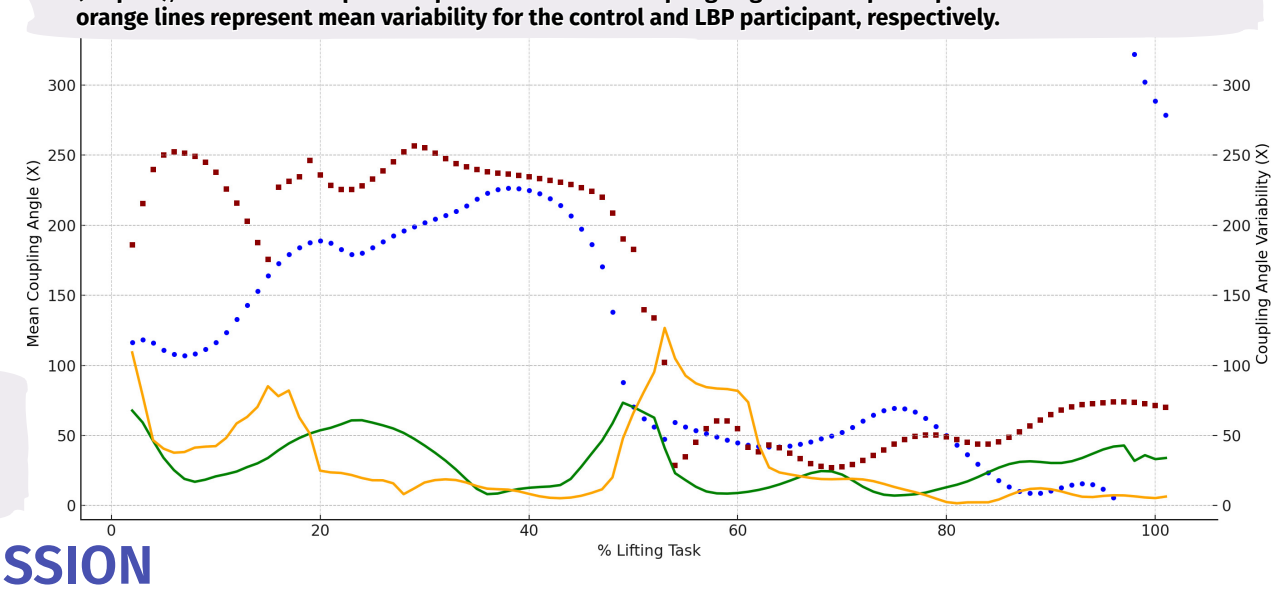
RESULTS

The participant with pain showed **more in-phase coordination** (87% vs. 70%), especially during descent (82% vs. 57%). Anti-phase was more common in the control (43% vs. 18% in descent). The LBP participant also showed **greater distal dominance** (73% vs. 52%), while the control had a more balanced profile. Global variability values were similar between participants with and without pain (30.7° vs. 29.8°, respectively). Coupling angles and variability profiles are illustrated in Picture 1.



Picture 2: Coupling angle classification heatmaps from the control (top two) and symptomatic subject (bottom two) during the lifting task, X-axis rotation. Green = in-phase, red = anti-phase, yellow = proximal dominance, blue = distal dominance. Colour scale indicates the proportion of frames classified within each pattern across the movement cycle.

Picture 1: Mean Coupling Angle and Variability. Blue circles represent the mean coupling angle for the control (no pain), and dark red squares represent the mean coupling angle for the participant with LBP. Green and orange lines represent mean variability for the control and LBP participant, respectively.



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DISCUSSION

Methodological heterogeneity across studies limits comparisons. Ippersiel et al.[1] shares conceptual similarity by using VC, but their inclusion of non-dominant categories and different oscillators (hip-lower lumbar and upper lumbar-lower lumbar) restricts comparison of joint dominance. Thus, only mean coupling angles were comparable, though this overlooks the temporal specificity of coordination analyses. However, **frame-by-frame mean coupling angle curves enables qualitative comparisons across studies.** Nevertheless, they reported less in-phase coordination and more variable behavior in the LBP group. Frame-by-frame analysis revealed distinct strategies, with both participants showing increased variability during phase transitions; however, the peak was sharper and more abrupt in the participant with pain, suggesting reduced control. This underscores the value of phase-specific analysis, as **global measures may miss task-relevant fluctuations**.

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