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Technical and measurement report

Using kinematics and a dynamical systems approach to enhance understanding of clinically observed aberrant movement patterns

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ABSTRACT

The objective of this technical paper is to demonstrate how graphing kinematic data to represent body segment coordination and control can assist clinicians and researchers in understanding typical and aberrant human movement patterns. Aberrant movements are believed to be associated with musculoskeletal pain and dysfunction. A dynamical systems approach to analysing movement provides a useful way to study movement control and coordination. Continuous motion angle–angle and coupling angle-movement cycle graphs provide information about coordinated movement between body segments, whereas phase-plane graphs provide information about neuromuscular control of a body segment. Examples demonstrate how a dynamical systems approach can be used to represent (1) typical movement patterns of the lumbopelvic and shoulder regions; (2) aberrant coordination in an individual with low back pain who presented with altered lumbopelvic rhythm; and (3) aberrant control of shoulder movement in an individual with observed scapular dysrhythmia. Angle–angle and coupling angle-movement cycle graphs were consistent with clinical operational definitions of typical and altered lumbopelvic rhythm. Phase-plane graphs illustrated differences in scapular control between individuals having typical scapular motion and an individual with scapular dysrhythmia. Angle–angle, coupling angle-movement cycle, and phase-plane graphs provide information about the amount and timing of segmental motion, which clinicians assess when they observe movements. These approaches have the potential to (1) enhance understanding of typical and aberrant movement patterns; (2) assist with identifying underlying movement impairments that contribute to aberrant movements: and (3) improve clinicians' ability to visually assess and categorize functional movements.

Physical therapists specialize in management of movement related disorders (APTA, 2001). An essential component of a physical therapy examination is visual assessment of movements as it is believed that aberrant movement is associated with musculoskeletal pain and dysfunction (Sahrmann, 2001). Therefore, a thorough understanding of the complex nature of functional movements is important for clinicians.

A commonly used approach for understanding typical and aberrant movement patterns focuses on the amount of motion at points in time by plotting group mean angular rotation of a body segment over a defined period along with between-subject variability (Fig. 1A)(Kadaba et al., 1990). This approach is limited because it does not provide information about how movement is coordinated between two or more body segments.

An angle–angle graph plots angular movement of one body segment against another and provides information about coordinated movement between segments (Esola et al., 1996; Ebaugh et al., 2005). Traditional use of angle–angle graphs for studying shoulder motion has focused on the amount of scapular motion at select points of humeral elevation (Fig. 1B). Although this approach provides important information, it does not provide an accurate understanding of coordinated motion between two body segments throughout an entire movement cycle. Furthermore, an

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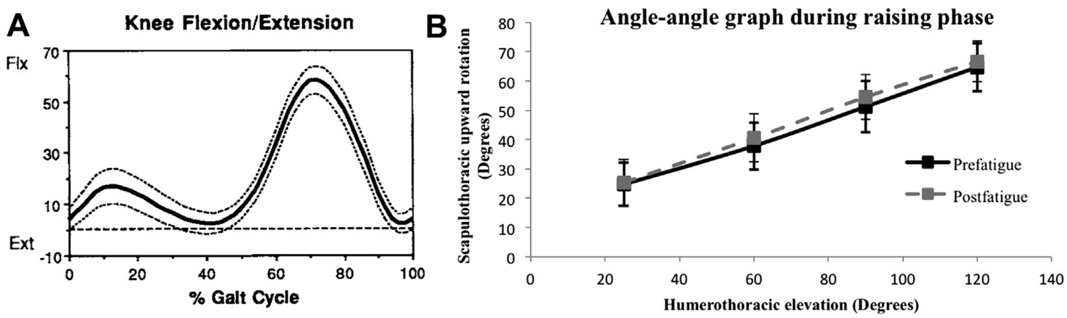

Fig. 1. Examples of graphs used to study movement patterns. (A) Knee motion curve that provides only angular motion of one segment during gait cycle. Mean knee angle (solid line) and one standard deviation (dotted lines) in sagittal plane during gait cycle in adults (Kadaba et al., 1990). (B) Angle–angle graph comparing prefatigue and postfatigue scapular upward rotation and standard error of the mean at 30°, 60°, 90°, and 120° of humeral elevation. It should be noted that the solid and dashed lines on the graph simply connect one data point to another and are not representative of actual data or movement patterns between plotted points.

angle–angle graph does not capture temporal information about moving segments.

A dynamical systems approach has been used to study movement control and coordination (Winstein and Garfinkel, 1989; Silfies et al., 2009). This approach includes use of continuous motion *angle–angle* and *coupling angle-movement cycle graphs* to provide information about coordinated movement between body segments, whereas *phase-plane graphs* provide information about neuromuscular control of a segment. Additionally, it is important to understand variability associated with typical movement patterns through use of variability bands (Garofalo et al., 2009). Collectively, these approaches have the potential to expand current understanding of typical and aberrant movement patterns, and help clinicians accurately categorize functional movements.

The purpose of this technical report is to discuss the use of a dynamical systems approach to improve understanding of typical and aberrant movements. Examples of application are provided for the shoulder and spine.

1. Angle–angle, coupling angle-movement cycle, and phase-plane graphs.

Use of continuous angular displacement data to generate angle–angle graphs focuses on the shape of the movement pattern, thereby providing information about movement coordination between body segments (Fig. 2A and B)(Winstein and Garfinkel, 1989). Although these graphs provide information about movement coordination, it is difficult to determine whether

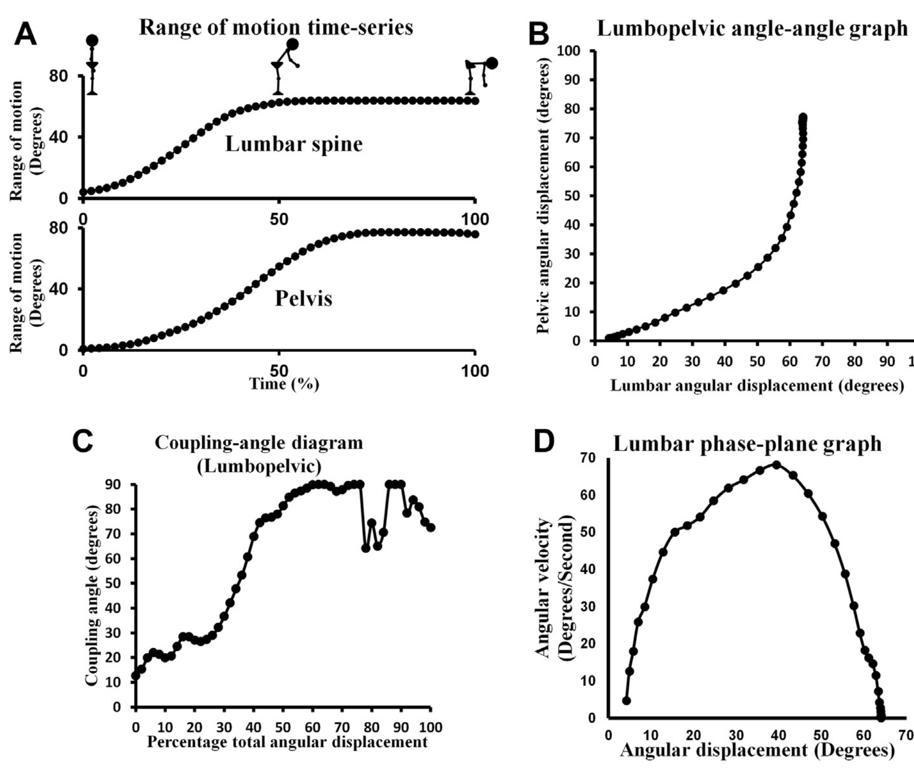

Fig. 2. Data collected from a trial of trunk forward bend in a subject without a history of low back pain. (A) Continuous angular displacement motion curves used to generate the angle–angle graph. (B). Angle–angle graph during standing forward bending. The slope of the line in this graph indicates the relationship or coordination of movement between the two segments. (C) Coupling angle-movement cycle graph during a forward bend movement. (D) Phase-plane graph of the lumbar spine during standing forward bend demonstrating typical smooth control of movement.