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Short communication

A new coordination pattern classification to assess gait kinematics when utilising a modified vector coding technique

Robert A. Needham*, Roozbeh Naemi, Nachiappan Chockalingam

CSHER, Faculty of Health Sciences, Staffordshire University, Leek Road, Stoke on Trent ST4 2DF, UK

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ABSTRACT

A modified vector coding (VC) technique was used to quantify lumbar–pelvic coordination during gait. The outcome measure from the modified VC technique is known as the coupling angle (CA) which can be classified into one of four coordination patterns. This study introduces a new classification for this coordination pattern that expands on a current data analysis technique by introducing the terms in-phase with proximal dominancy, in-phase with distal dominancy, anti-phase with proximal dominancy and anti-phase with distal dominancy. This proposed coordination pattern classification can offer an interpretation of the CA that provides either in-phase or anti-phase coordination information, along with an understanding of the direction of segmental rotations and the segment that is the dominant mover at each point in time. Classifying the CA against the new defined coordination patterns and presenting this information in a traditional time-series format in this study has offered an insight into segmental range of motion. A new illustration is also presented which details the distribution of the CA within each of the coordination patterns and allows for the quantification of segmental dominancy. The proposed illustration technique can have important implications in demonstrating gait coordination data in an easily comprehensible fashion by clinicians and scientists alike.

1. Introduction

Vector coding is a data analysis technique that can be applied to an angle–angle diagram to quantify the movement coordination between two body segments over time. Using a modified technique presented by Sparrow et al. (1987), Hamill et al. (2000) described the 'coupling angle' (CA) which refers to the vector orientation between two adjacent time points on an angle–angle diagram relative to the right horizontal (Fig. 1a). Based on the polar plot position which ranges between 0° and 360°, the CA can be classified to a coordination pattern. For example, a vector orientation of 0° or 180° indicates the proximal segment is moving and the distal segment is in a fixed position, while 90° and 270° specify the opposite (Hamill et al., 2000). However, during a dynamic movement it is uncommon for one segment to be in a fixed position for an extended period of time. Therefore, in an attempt to quantify rear-foot and fore-foot coordination, Chang et al. (2008) expanded on the original interpretation of the CA by dividing the unit circle into 45° 'bins' and classifying the coordination pattern as in-phase (two segments rotate in the same direction), anti-phase (two segments rotate in an opposite direction), proximal phase (rear-foot dominancy) or distal phase (fore-foot dominancy) (Fig. 1b). Whilst the results of this study provided an insight into the functional workings of the foot, and offered a new perspective for an understanding of a musculoskeletal condition such as plantar fasciitis, as such this is the only approach currently employed to classify the CA to quantify the coordination pattern.

Needham et al. (2014) implemented the data analysis technique by Chang et al. (2008) to quantify lumbar–pelvic coordination during gait. In this study a new illustration was also presented, which included time-series information of both the CA and global segmental angle data. Needham et al. (2014) noted that pelvis dominancy was the common coordination pattern during the loading response phase of gait, and this was attributed to a greater range of motion (ROM) of the pelvis in comparison to the lumbar spine. However, global segmental angle data revealed an anti-phase relationship during this pelvis dominated phase, and detailed important information which was not provided in the coordination pattern classification by a previous study (Chang et al., 2008).

Therefore, the aim of this paper was to classify the CA to a coordination pattern which represents phase dominancy (in-phase or anti-phase), segmental dominance and provides information on the direction of segmental rotations. Furthermore, this approach will help to assess the ROM in a continuous way rather than

* Corresponding author. Tel.: +44 1782 294972; fax: +44 1782 294321.
E-mail address: r.needham@staffs.ac.uk (R.A. Needham).

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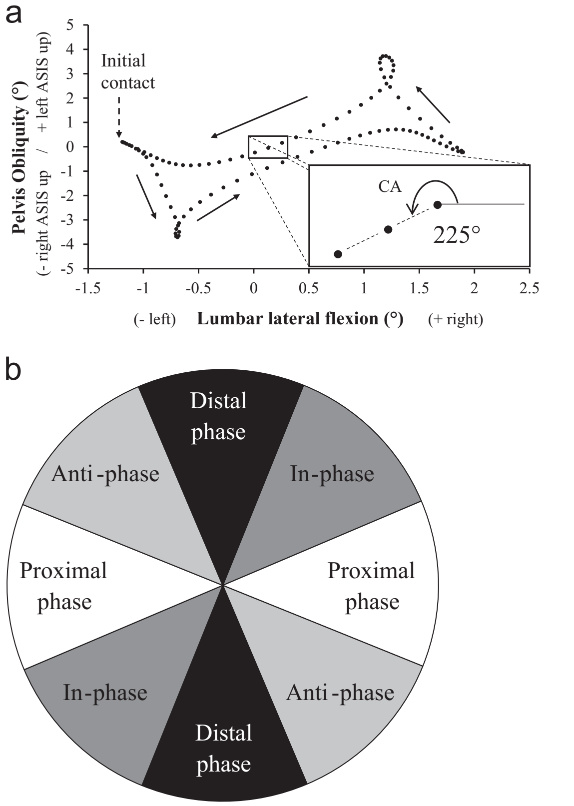

Fig. 1. An angle–angle plot representing pelvis obliquity and lumbar lateral flexion during gait. The inset provides an expanded view of one CA (a). A polar plot showing the coordination pattern classification scheme by Chang et al. (2008) (b).

measuring its magnitude within discrete time frames. Such information will assist in the interpretation of the CA and can have implications in clinical settings (Seay et al., 2011).

2. Methodology

Eight male participants (mean ± SD: age: 21 ± 2.83 years, height: 180.75 ± 9.6 cm, body mass: 72.86 ± 10.57 kg) with no history of musculoskeletal impairments gave written consent to participate in the study. Ethical approval was sought and granted from the University Research Ethics Committee.

Pelvis and lumbar spine kinematic data was collected (100 frames per second) over five walking trials using an eight camera motion capture system (VICON, Oxford, UK). Gait events (initial contact and toe off) were identified using two AMTI-OR6 force platforms (AMTI, USA). The pelvis segment was defined by the placement of reflective markers on the anterior and posterior iliac spines, and a 3D cluster tracked lumbar spine movement in the region of L3 (Needham et al., 2015). For further information on method procedures and for the calculations regarding the VC technique, readers are directed to a study by Needham et al. (2014).

2.1. New coordination classification

In Fig. 2, portions of the polar plot are colour coded and represent the four coordination patterns proposed in this study. These include in-phase with proximal dominancy (white), in-phase with distal dominancy (light grey), anti-phase with proximal dominancy (dark grey) and anti-phase with distal dominancy (black).

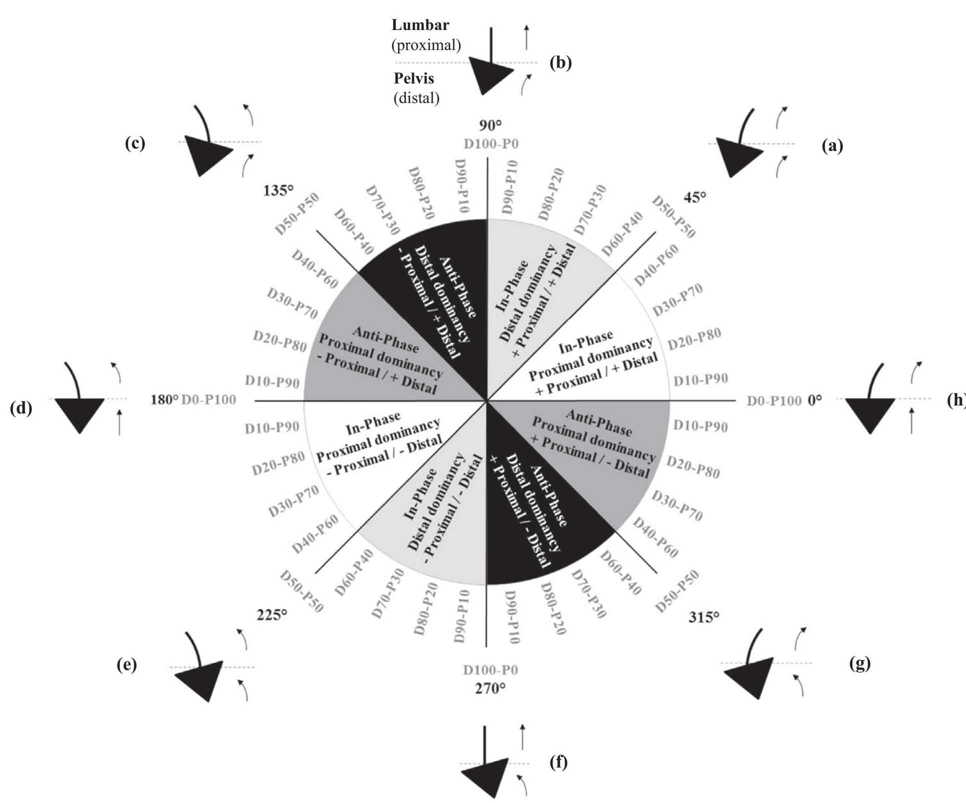

Fig. 2. The new coordination pattern classification proposed in the current study. Segmental dominancy is shown around the circumference of the polar plot (grey text) with the inclusion of visual illustrations to show the coordination pattern between the lumbar region (proximal) and the pelvis (distal) at specific CA's (a–h).