

DETECTING ASYMMETRIES IN BRACED AND UNBRACED LIMBS

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INTRODUCTION

Gait function depends on both coordinated motion of the body and the timing of that motion (Perry, 1992). Unfortunately, univariate measurements lack the ability to capture the spatio-temporal complexity of the gait cycle, and provide little information on the behavior of other joints. For example, quantitative assessments of joint ranges of motion are typically conducted at discrete and easily defined points in time (e.g., heel-strike, mid-stance, toe-off) (Vaughan, 1992). Such measures fail to capture the motion that occurs between these discrete temporal events, and fail to assess how problems at one joint affect other joints.

This study introduces two new quantitative metrics to address these limitations. These metrics identify (i) which joint angles are affected by a perturbation, (ii) the timing during the gait cycle when these effects are prominent, and (iii) how a perturbation at one joint affects ipsilateral and contralateral joints. To test these metrics, a data set with known asymmetries was created by restricting joint range of motion using a brace at the ankle or knee. By creating a known and repeatable gait asymmetry in a controlled population, we can better assess how effectively different approaches detect, track, and quantify changes in symmetry. This simulated data set is particularly advantageous because normal gait can be compared directly to perturbed gait. The proposed approach identifies regions of the gait cycle most affected by bracing and provides quantitative metrics that can be used to describe and compare motions.

METHODS

The knee or ankle of the dominant leg was constrained by a brace (DonJoy, Vista, CA) in ten healthy male subjects, mean age 21 ± 2 (SD) yrs. All subjects were experienced treadmill walkers, right leg dominant, and walked at a self-selected speed. Subjects walked on a treadmill without bracing, with the knee braced, and with the ankle braced.

Kinematic data were collected using a six camera motion analysis system at 120 Hz (Vicon, Oxford, UK Model 460) and were used to calculate traditional parameters (TP) and newly developed regions of deviation (ROD) parameters. TP were: joint angle range of motion, step length, single leg support time, foot rotation angle, and step width. Bilateral TP values were used to calculate symmetry indices to quantify asymmetry (Becker, 1999).

The first metric, symmetry regions of deviation (SROD), identifies regions of deviation in bilateral joint angle symmetry.

$$SROD = \begin{cases} \left(\frac{\sum_{i=1}^{10} \Delta\theta_i - SNorm}{10} \right) & , \Delta\theta_i > SNorm \\ 0 & , \Delta\theta_i \leq SNorm, \quad i = \text{subject} \end{cases}$$

where: $\Delta\theta = \theta_{Right} - \theta_{Left}$ and $SNorm = \Delta\theta_{mean} - \Delta\theta_{SD}$

The second metric, individual regions of deviation (IROD), identifies regions of deviation in an individual joint angle.

$$IROD = \begin{cases} \left(\frac{\sum_{i=1}^{10} \theta_i - INorm}{10} \right) & , \theta_i > INorm \\ 0 & , \theta_i \leq INorm, \quad i = \text{subject} \end{cases}$$

where: $INorm = \theta_{mean} \pm \theta_{SD}$

Paired t-tests were used to compare both univariate gait parameters and the peak SROD and IROD values. Repeated measures ANOVA tests were used with symmetry index values. Significant main effects were further examined by LSD post-hoc comparisons. ($\alpha = 0.05$)

RESULTS AND DISCUSSION

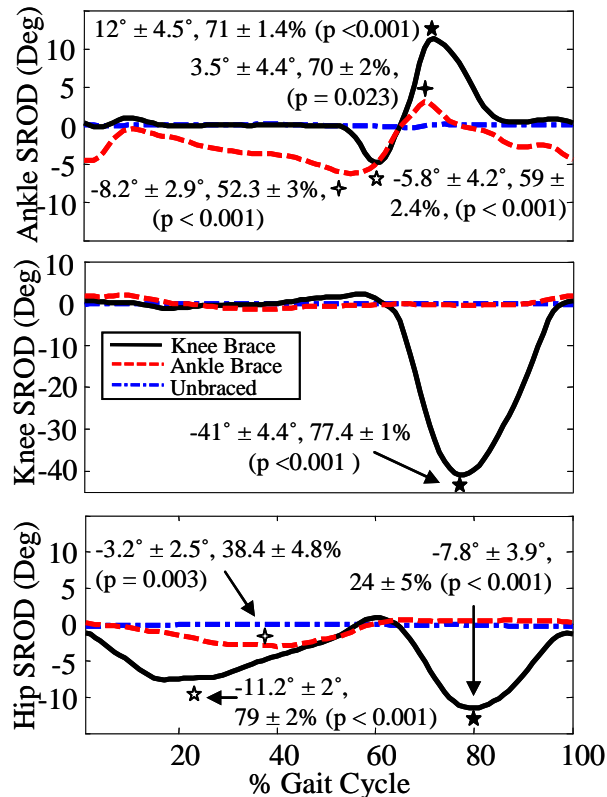


Figure 1: Plots of the average symmetry ROD (SROD) values. Filled five-point stars indicate knee-braced (KB) peak values during swing, and filled four point stars mark ankle-braced (AB) peaks during swing. Unfilled four point stars identify AB peaks during stance, and unfilled five point stars mark KB peaks during stance.

Bilateral values for ankle, knee, and hip joint range of motion and single leg support time showed increased asymmetry in gait due to bracing. Step width was also increased by bracing. The ROD parameters showed that significant asymmetries had

been created between joint angle pairs, and that knee bracing increased asymmetries in joint behavior during swing, while ankle bracing tended to affect stance.

Traditional parameters provide gross indicators of asymmetric gait behavior. ROD parameters detect asymmetry, but also identify the phases of the gait cycle with the largest deviations, and give information about the impact of gait perturbation on neighboring joints. This additional information could be used in a clinical setting to identify, track and characterize asymmetric behavior.

SUMMARY/CONCLUSIONS

Gait function depends on both coordinated motion of the body and the timing of that motion. As a result, traditional gait analysis parameters have limited ability to describe the impact of known perturbations on gait function because they do not provide specific temporal information. ROD analysis provides quantitative information on the effect of bracing throughout the gait cycle and how contralateral and ipsilateral joint angular behavior is modified. This new analysis links coordinated limb movement to temporal events in the gait cycle for improved gait analysis.

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