

Assessing Kinematic Methods of Structuring Gait

Overview - Abstract

This tutorial is a comprehensive walkthrough of a research investigation presented at the Ontario Biomechanics Conference (OBC) 2025.

The study, titled “Assessing Different Kinematic Methods of Structuring Gait”, explores how gait events can reliably detected using only kinematic data, without access to lab-based kinetic systems such as force plates or instrumented treadmills.

Research Question: Are kinematic event detection methods able to reliably structure biomechanical waveforms in the gait cycle?

The tutorial has been designed for biomechanics researchers, students, and clinicians interested in alternative gait cycle structuring approaches, especially in field-based or markerless motion capture settings.

Introduction

In gait analysis, the ability to structure biomechanical waveforms into gait cycles is crucial for analyzing joint angles, segment kinematics, and for computing various gait measures like step length and phase durations.

Traditionally, gait cycles are structured using kinetic event detection methods based on ground reaction forces (GRFs), which provide an objective and reliable signal for detecting HS and TO. However, kinetic data acquisition requires expensive equipment and comes with many other downsides.

Given these limitations, researchers have developed a range of kinematic event detection algorithms that rely on marker trajectories or derived joint kinematics to infer gait events. While these methods are promising, their accuracy and robustness - especially under varying walking speeds and among diverse populations- need validation.

The aim of this tutorial is to present a step-by-step guide for using HAS-Motion software tools, specifically Visual3D, to process gait data and compare several kinematic-based methods against the kinetic-based gold standard.

Dataset Description

A public dataset of overground and treadmill walking kinematics and kinetics in healthy individuals

[Claudiane A Fukuchi](#)¹, [Reginaldo K Fukuchi](#)², [Marcos Duarte](#)^{1 2}

Affiliations + expand

PMID: 29707431 PMCID: [PMC5922232](#) DOI: [10.7717/peerj.4640](#)

[Link to](#)

Article

This investigation uses the publicly available dataset from [Fukuchi et al. \(2018\)](#), which provides overground and treadmill walking data for 42 healthy adults.

The dataset consists of 24 younger participants (mean age ~27.6 years) and 18 older participants (mean age ~62.7 years). Each subject completed both treadmill and overground walking trials across a range of speeds. For each trial, 3D kinematic data was captured using a 26-marker lower-body configuration at a sampling rate of 150 Hz, and ground reaction forces were recorded from an instrumented treadmill at 300 Hz. Metadata for each participant includes height, weight, segment length, sex, leg dominance, and treadmill speed.

This tutorial focuses exclusively on **treadmill trials** and analyzes only **left-side events** (LHS and LTO). This simplifies gait cycle definitions to the interval between two identical events on the same foot, which is essential for consistent waveform normalization.

Sample Data Download and Contents

To facilitate learning and application, we provide a premade ZIP archive containing all required files.

- Includes a Visual3D preprocessing pipeline (**Preprocessing_Pipeline**) that performs kinetic event detection and computes the necessary joint kinematics.
- **PREPROCESSED_PARTICIPANTS**: Preprocessed CMZ files for all 42 participants with the preprocessing pipelines applied.
- **FULL_PROCESSED_PARTICIPANTS**: Fully processed CMZ files for all 42 subjects where all methods and events have already been applied to the data.
- **METHOD PIPELINES + MASTER**: Folder containing individual Visual3D pipeline scripts for each kinematic method (e.g., Zeni Method 1+2, DeAsha, Hreljac, etc.) and a master pipeline script that applies all methods and computes the metric of cycle duration.
- **WBDSmodel.mdh**: Original model file that defines the lower limb segments using the 26 anatomical markers.
- **AutoFormatted_Gait_Data_Final**: Excel sheet containing resultant exported data from processing - listing method, trial and cycle instance+duration. This format is used for more accessible manipulation during analysis in Python.

Copies of the literature for the various kinematic methods used are also included in the ZIP archive:

- Zeni et al. (2018) Method 1 and 2
 - DeAsha et al. (2012)
 - Hreljac & Marshall (2000)
 - OConnor et al. (2007)

Notes

This tutorial is based on a research project presented at the Ontario Biomechanics Conference (OBC) 2025 titled “**Assessing Different Kinematic Methods of Structuring Gait**”.

The goal of this tutorial is to help users replicate the research process and understand how to structure gait cycles without relying on kinetic data (e.g. from force plates or instrumented treadmills). Instead, we will use kinematic data and implement several established event detection algorithms using Visual3D.

This tutorial is intended for users who either do not have access to lab-grade kinetic instrumentation, or see this equipment as unideal for their environment- in the case of a field-based or markerless system.

Objectives

- Introduce and implement kinematic-based gait event detection methods from peer-reviewed literature.
- Provide a step-by-step approach to structuring gait cycles in Visual3D.
- Compare the derived cycles to kinetic-based baseline cycle.
- Use downloadable data, Visual3D pipelines, and batch scripting workflows in order to simulate the process of this investigation.

Background and Rationale

Traditionally, gait cycle events such as Heel Strike (HS) and Toe Off (TO) are defined using force thresholds derived from ground reaction force (GRF) data. This method is reliable but dependent on lab based equipment.

Kinematic methods detect HS and TO using joint angles, segment velocities, or spatial relationships between anatomical markers. Although these methods are not perfect, they are crucial for field-based studies, clinical gait analysis, and wearable-only workflows.

In our project, we evaluated the following kinematic event detection methods:

- Zeni et al. (2018) Method 1 and 2
 - DeAsha et al. (2012)
 - Hreljac & Marshall (2000)
 - O'Connor et al. (2007)
- **Max Knee Angle Method** - Local maximum events for knee reaching peak flexion.
- **Hip Surpasses Heel** - event placed when leading hip joint center overtakes opposite foot.

Each method identifies gait events based on unique kinematic patterns, such as:

- Local minima/maxima in foot marker trajectories.
- Peak knee flexion or extension.
- Spatial relationship between foot and hip joint centers.

Dataset Description

This tutorial uses the [Fukuchi et al. \(2018\)](#) walking dataset.

- Journal Article: [A public dataset of overground and treadmill walking kinematics and kinetics in healthy individuals.](#)
- **Participants:** 42 healthy adults (24 younger, 18 older)
- **Trials:** 5-8 treadmill walking trials per participant, increasing speed per trial.
- Data collected includes marker trajectories and kinetic data from an instrumented treadmill.

Important Notes:

- Only left-side gait events were analyzed.
- Data was pre-processed to extract joint angles, segment positions and other features required for each algorithm. This will be included in the sample data.

Downloads

The ZIP File for this tutorial can be downloaded [here](#). This provides files for the different steps of the workflow process of the research.

Compute Kinematic Parameters

Before applying the kinematic event methods, compute the joint angles and positions required. This typically includes the **Compute_Joint_Angle** and **Compute_Segment_Position**.

The base pipeline with all preprocessing steps. This will be used before applying any method-specific event logic.

Step 1: Set up your environment

Organize the workspace by participant. Make sure each trial has:

- A working biomechanical model.
- Joint angle outputs.

Step 2: Apply Kinetic Baseline Events

Use **Automatic_Gait_Event** command in Visual3D to generate Left Onset (LON) Kinetic events. These will serve as the gold-standard baseline.

```
Automatic_Gait_Events
! /FRAME_WINDOW=8
! /USE_TPR=TRUE
! /TPR_EVENT_INSTANCE=1
```

;

These events use vertical ground reaction force thresholds to identify HS/TO.

Results Summary

The project found that:

- Zeni's method 1 (HS foot vertical position), method 2 (TO foot vertical position), and peak knee angle method produced the most reliable cycles compared to the kinetic baseline.
- Some methods introduced variability as speed increased.
- Kinematic methods are viable alternatives in environments without force plates, provided method-specific biases are considered.

From:

<https://has-motion.com/wiki/> - Wiki Documentation Site

Permanent link:

https://has-motion.com/wiki/doku.php?id=visual3d:tutorials:events:kinematic_event_detection&rev=1748624766

Last update: **2025/05/30 17:06**

