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Principal component analysis (PCA) is a multi-variate statistical analysis that reduces the high-dimensional matrix of correlated, time-varying signals into a low-dimensional and statistically uncorrelated set of principal components (PCs). These PCs explain the variance found in the original signals and represent the most important features of the data, e.g., the overall magnitude or the shape of the time series at a particular point in the stride cycle. The value of each particular subject's score for the individual PCs represents how strongly that feature was present in the data.

More detail on the mathematics behind PCA can be found on our page: [The Math of Principal Component Analysis \(PCA\)](#).

## The Utility of PCA

When we analyse biomechanical signals, we could identify many isolated quantities (e.g. maximum and minimum values) and compare the signals based on these metrics. Given that there is a common underlying shape to all of these signals, however, it can be more informative to use a multivariate statistical technique that can capture this basic shape and compare the shape of each signal to this underlying shape.

## Visualizing PCA Results

Visualizing PCA results can be done using either [Sift](#) or [Inspect3D](#)

Information on visualizing PCA results in Sift can be found [here](#).

Information on visualizing PCA results in Inspect3D can be found [here](#).

## Reference

Our implementations of Principal Component Analysis is based on the article:

Deluzio KJ and Astephen JL (2007) Biomechanical features of gait waveform data associated with knee osteoarthritis. An application of principal component analysis. *Gait & Posture* 23. 86-93 ([pdf](#)) **Abstract** This study compared the gait of 50 patients with end-stage knee osteoarthritis to a group of 63 age-matched asymptomatic control subjects. The analysis focused on three gait waveform measures that were selected based on previous literature, demonstrating their relevance to knee osteoarthritis (OA): the knee flexion angle, flexion moment, and adduction moment. The objective was to determine the

biomechanical features of these gait measures, related to knee osteoarthritis. Principal component analysis was used as a data reduction tool, as well as a preliminary step for further analyses to determine gait pattern differences between the OA and the control groups. These further analyses included statistical hypothesis testing to detect group differences, and discriminant analysis to quantify overall group separation and to establish a hierarchy of discriminatory ability among the gait waveform features at the knee. The two groups were separated with a misclassification rate (estimated by cross-validation) of 8%. The discriminatory features of the gait waveforms were, in order of their discriminatory ability: the amplitude of the flexion moment, the range of motion of the flexion angle, the magnitude of the flexion moment during early stance, and the magnitude of the adduction moment during stance. Check out a more recent article using PCA on whole-body kinematics:

Eveleigh KJ, Deluzio KJ, Scott SH and Laende EK (2023) Principal component analysis of whole-body kinematics using markerless motion capture during static balance tasks. *Journal of Biomechanics*. [1]

**Abstract** Balance tests have clinical utility in identifying balance deficits and supporting recommendations for appropriate treatments. Motion capture technology can be used to measure whole-body kinematics during balance tasks, but to date the high technical and financial costs have limited uptake of traditional marker-based motion capture systems for clinical applications. Markerless motion capture technology using standard video cameras has the potential to provide whole-body kinematic assessments with clinically accessible technology. Our aim was to quantify poses and movement strategies during static balance tasks (tandem stance, single limb stance, standing hip abduction, and quiet standing on foam with eyes closed) using video-based markerless motion capture software (Theia3D) and principal component analysis to examine the associations with age, body mass index (BMI) and sex. In 30 healthy adults, the mean poses for all balance tasks had at least one principal component (PC) that differed significantly by sex. Age was significantly associated with the PC describing leg height for the hip abduction task and erect posture for the quiet standing task. BMI was significantly associated with the PC capturing knee flexion in the single leg stance task. The movement strategies used to maintain balance showed significant differences by sex for the tandem stance pose. BMI was correlated with PCs for movement strategies for hip abduction and quiet standing tasks. Results from this study demonstrate how markerless motion capture technology could be used to augment analyses of balance both in the clinic and in the field. The fundamentals of Principal Component Analysis for our implementations and the presented article are derived from the [Research Methods in Biomechanics textbook](#).

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