Development of a data-driven framework for classifying movement patterns

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Abstract

Introduction: Movement screens are used to identify abnormal movement patterns that: i) are indicative of dysfunction, or ii) may increase risk of injury or hinder performance. Abnormal patterns are traditionally detected through visual observations by a coach, clinician, or ergonomist[1]. Quantitative, or data-driven methods can increase objectivity, remove issues related to inter-rater reliability, and offer the potential to detect new and important features that may not be observable by the human eye.[1,2] Applying pattern recognition techniques to kinematic or kinetic data can provide an objective, data-driven method to identify unique and statistically important patterns[3], an important first step to objectively classify non-optimal or abnormal movement. The objective of this work was to develop and test a data-driven framework for classifying movement patterns.

Methods: The proposed framework consists of five parts: a) a movement task or screen, b) collection and pre-processing of desired kinematic/kinetic data, c) principal components analysis (PCA) to identify key patterns and features, d) machine learning to classify based on chosen criteria, and e) scoring of movement quality (Figure 1). To test the framework and provide proof-of-concept and effectiveness, we analyzed 3-D whole-body kinematic data (i.e. 26 positional trajectories x 3 axes) from 542 athletes during performance of a movement screen consisting of seven dynamic, functional movements (i.e. bird-dog, drop jump, T-balance, step-down, L-hop, hop-down, and lunge). PCA was used as the feature selection/pattern recognition technique, and linear discriminant analysis (LDA) was chosen as the machine learning technique with skill level (i.e. elite vs. novice) as the classifier with PC scores as the predictors. Finally, each athlete's data were projected onto the linear discriminant function to calculate the likelihood of being either an elite or novice athlete.

Results: Depending on the movement, the validated LDA models accurately classified 70.7-82.9% of athletes as either elite or novice, while also providing interpretable quality scores for each athlete. The sensitivity of the model (probability of an elite being correctly classified) ranged from 66.2%-75.8% and the specificity (probability of a novice being correctly classified) ranged from 75.6%-86.8% depending on the task.

Discussion: We have provided proof that this framework is effective at objectively classifying and scoring athletes based on skill level. The benefit of this framework is its flexibility in terms of accommodating several different movement and data types, as well as pattern recognition and machine learning/scoring techniques. Currently, we are evaluating framework performance with other types of data, machine learning techniques , and classifiers.

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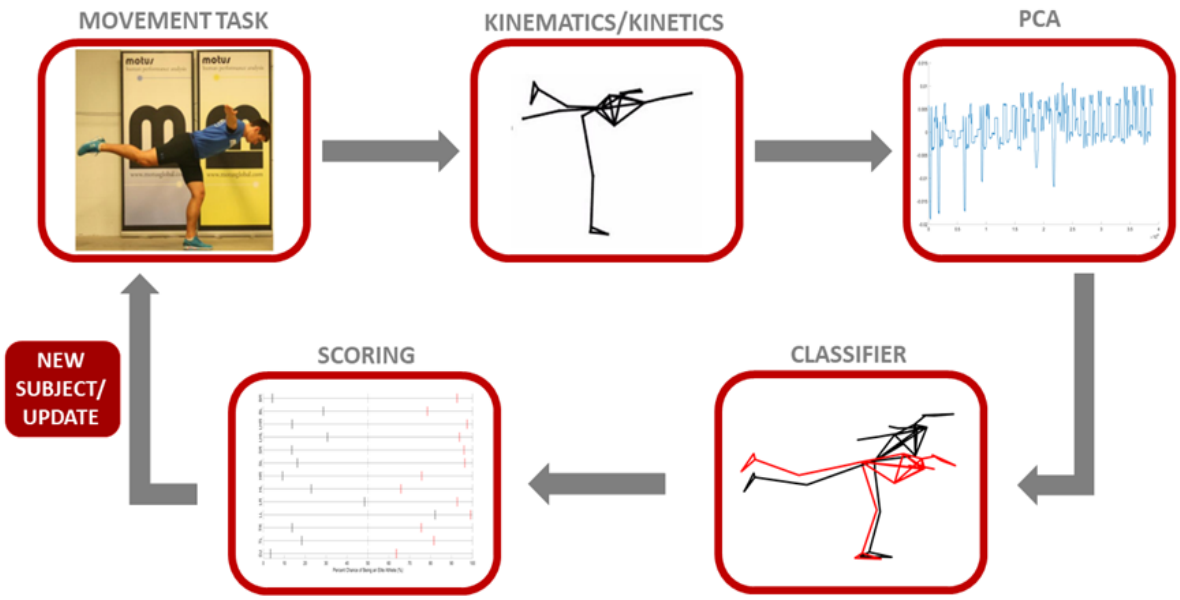

Figure 1. The schematic of the developed framework for classifying movement. The proposed framework consists of five parts: a) a movement task or screen, b) collection and pre-processing of desired kinematic/kinetic data, c) principal components analysis (PCA) to identify key patterns and features, d) machine learning to classify based on chosen criteria, and e) scoring of movement quality.