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An extended index to quantify normality of gait in children

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Abstract

Clinical gait analysis aims to quantify and assess the mechanics of walking and identify deviations from 'normal' movement patterns. To facilitate the use of clinical equipment, protocols are required to process data and produce a few meaningful summary measurements which can, in turn, be used to flag gait abnormalities. Earlier work produced a one-dimensional index of gait, calculated from sagittal hip, knee and ankle rotation angle patterns. The objective of this study was to extend the original index, incorporating kinematic and kinetic data from multiple planes, while allowing for correlations between component measures. A one-dimensional index of normal gait was developed, based on normative gait data ($N = 45$ children, aged 3–13 years). The new one-dimensional index was calculated using correlation patterns between seven component indices, each of which has diagnostic interpretation. The effectiveness of the new index was tested using immature normative data ($N = 14$) and hypotonic data ($N = 10$). Approximately 85% of immature normative children and 100% of hypotonic children were classified as either unusual or extreme by the one-dimensional index. These data reduction protocols improve objective gait analyses in the clinical setting.

Keywords: Gait; Kinematics; Kinetics; Index of normality

1. Introduction

Abnormal gait patterns are typically identified by comparing patient movement patterns to age-matched normative data. Researchers have used various types of classifiers to reduce the dimensionality of gait data and extract essential information about an individual's or population's gait patterns. Most of these classifiers can be categorized as either parameterization or waveform techniques.

Parameterization techniques extract instantaneous values of amplitude and time from the gait curves [1–6]. These techniques use a fraction of the available data in gait. It can be difficult to identify required peaks and valleys in a clinical waveform, which may have very different profiles. Furthermore, these methods do not address information that may lie in the pattern of the waveform. Waveform classifiers attempt to capture the entire gait curve. Such methods may include Fourier analysis [7,8], bootstrap methods [8,9], principal components analysis [10–12], and neural network and pattern recognition techniques [13–20].

The objective of this work was to develop a systematic method of data reduction, incorporating a set of clinically meaningful and measurable kinematic and kinetic gait parameters from multiple planes and segments. Changes in these parameters over the course of a gait cycle and interrelationships between component measurements are incorporated into the classifier. The classifier is based on previous work by Tingley et al. [7], which established a one-dimensional index of normality to classify individuals as 'normal', 'unusual' or 'abnormal' based on their deviation, from San Diego mean normative data. A key idea behind that classifier was the use of Mahalanobis distance [21] to measure 'squared distance from the mean' for correlated,

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