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An index to quantify normality of gait in young children

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Abstract

Gait patterns are often described by recording the changes in angular rotation of such joints as the hip, knee and ankle, during a complete cycle. Each joint exhibits distinctive behavior throughout the gait cycle, and abnormal gait can be described by measuring departure from a typical (mean) joint rotation curve. Standard techniques for observation of gait patterns produce large sets of data. Data reduction is achieved in this work by locating primary directions of variation from mean behavior. Variation from the mean can then be summarized with a one-dimensional statistic, thought of as a squared distance from the population mean. Percentiles of this one-dimensional index can be calculated, enabling classification of a child as normal, unusual or abnormal. A key feature of this analysis is that it is applied across multiple joint angle curves and their derivatives, thus providing a measure that takes account of the interactions between the curves as well as their individual characteristics. A data base of 348 gait cycles, collected from normal children, aged 3–7, were analyzed. Data on each child were stored in a 36-dimensional vector. Most information on patterns of variation among normal children can be stored in a smaller 11-dimensional vector, which can be used for diagnostic purposes. Performance of the one-dimensional index of gait is demonstrated on data from very young children, and on children, up to age 7, who were born prematurely.

Keywords: Gait analysis; Multivariate statistics; Sagittal joint angles

1. Introduction

Gait analysis produces large amounts of data to describe movement. Typically these data include both measures such as walking speed, and gait events which are not a function of time, as well as joint angles, forces, and moments which are presented as functions of the percent of the gait cycle. In recent years principal component analysis (PCA) has become a widely used method to try to extract information from the bulk of data collected to describe gait. There has also been considerable interest in methods which can produce single indices to characterize whether a person's gait falls within the normal range.

A considerable literature exists which quantifies the mean values for various time varying measures of gait and the range of variability which may be expected in individual curves. For example, Sutherland et al. [1] describe joint angles and their associated variability for children grouped in 10 age categories. Winter [2] provides similar data for adult and elderly gait and Lasko et al. [3] quantify the within and between person variability which may be expected in measured joint angles. These measures and reports all rely on a largely qualitative assessment of whether an individual falls within the 'normal' bounds and do not address the question of the interaction between the curves.

PCA methods provide a way to assess the deviations from the mean and interactions between curves. Deluzio et al. [4] provide a detailed description of the PCA method. They applied PCA individually to estimates of bone on bone forces, net moments and knee angles to quantify the deviation from 'normal' of individuals with osteoarthritis, using a group of asymptomatic elderly controls. Their analysis considered the entire shape of the curves, but did not provide an overall measure of the interaction between the curves. Sadeghi et al. [5] recently reported a similar analysis of flexor extensor power at the hip, but also focussed on

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