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An index for quantifying deviations from normal gait

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Abstract

A method is derived to calculate the amount by which a subject's gait deviates from an average normal profile, and to represent this deviation as a single number. The method uses principal component analysis to derive a set of 16 independent variables from 16 selected gait variables. The sum of the square of these 16 independent variables is interpreted as the deviation of the subject's gait from normal. Statistical tests of the method's validity and an initial demonstration of its clinical utility are included. It is found that using this index, increasing clinical involvement corresponds to increasing index score. © 2000 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

Gait analysis provides an effective tool for evaluating and quantifying the effects of a surgical intervention or other treatment on a patient's gait [1]. An experienced clinician can make a subjective evaluation as to whether a patient's gait has become more normal following intervention and, with the gait analysis data, quantify the specific features of the gait that have changed. However, even with the assistance of gait analysis, objectively quantifying the degree to which a patient's gait has improved following an intervention remains difficult.

Most research studies using gait analysis have relied on comparisons of a limited number of specific gait characteristics to evaluate the effects of surgical procedures [2–6]. Such studies ignore the high degree of correlation that exists between various aspects of an individual's gait. Peak knee flexion during gait, for example, has been previously shown to be highly dependent on walking speed [7]. Similarly, hip flexion depends on the position of the pelvis, knee flexion and ankle dorsiflexion both depend on the orientation of the shank, and hip rotation and foot progression angle are highly coupled. In only a few cases have techniques, based on multivariate statistics that attempt to account for such correlation, been used to describe gait patterns. For example, Mah et al. [8] apply principal component analysis to time series functions of eight measured kinematic variables in order to determine three time series principle components describing over 90% of the information in the gait data. In addition, Loslever et al. [9–11] use a correspondence factor analysis method to describe different walking patterns within a group of normal subjects.

To accurately evaluate the extent of gait deviations from normal gait, or to assess the changes in a gait resulting from a specific treatment, it is important to consider not only how each feature of the gait pattern has changed but also how the relationship between the features changed. To evaluate whether a specific gait variable is normal, abnormal, or improved following treatment, the natural correlation that exists between gait variables must be determined. For this reason multivariate statistical techniques are used to develop a measure of how closely an individual gait pattern approaches normal. This 'closeness' is referred to as the normalcy index.

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