Discussion

The GPS and the GVS components of the MAP can be considered to have high criterion-related validity relative to clinician judgments. Although kinematic judgments are only a part of clinical decision making associated with interpretation of gait pathology, we propose that the MAP may be useful for clinicians to complement traditional kinematic data presentation. As clinical decision making requires consideration of individual joint kinematics, we suggest that GVS scores may reflect clinician judgments more closely than an overall gait index. Thus, a clear potential benefit of the GPS over other single gait index outcome measures is the provision of MAP GVS components. GVS components may also provide additional information when used as outcome measures of intervention.

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A Bayesian network prototype for CP gait classification

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Summary

Bayesian Networks (BN) were used for classifying gait patterns registered through gait analysis (GA) and primary deficits.

Conclusions

This pilot study highlights the strength of BN to model complex gait data. Despite the limited number of patients available to train the BN ($n=40$), a modest performance for automatic clinical gait pattern recognition at the ankle and knee was achieved.

Introduction

This study applies BN, because of their potential to cope with the complexities of gait data, and to automatically classify gait patterns of children with cerebral palsy (CP) into predefined, clinically relevant groups based on gait analysis (GA) and clinical exam data.

Patients, materials and methods

Since the BN required predefined groups, a new comprehensive classification describing gait deviations in all lower limb joints and motion planes, was created by multidisciplinary experts, based on clinical expertise and classifications described in literature. This study focused on the sagittal plane classification of knee and ankle in stance and swing. Gait analyses of children with CP, (<12 years, no history of surgery and recent BTX-A), with clinical examination data (32 parameters) and two to three gait trials (kinematics and kinetics, 39 gait parameters per trial) were included.

Results

Detailed qualitative and quantitative classification rules were defined based on the multidisciplinary discussion with the experts and an age-related normative database, enabling both subjective and automatic classification. A pioneer BN, including nodes (gait variables), arcs (linking variables) and underlying Condition Probability Tables (CPT) (describing how variables are related) was then constructed. Spasticity and strength measures were also included in the BN as a top layer of nodes. Fifty children (9.6 ± 2.3 years, 32 diplegia, 18 hemiplegia) met all criteria and were classified according to the new classification. A BN was implemented in Netica[®] (Norsys Software Corp.) and subjected to a training phase with gait data of 40 randomly selected children. Subsequently, a test phase was executed with the gait data of the remaining 10 children, evaluating its performance. The original BN had an error rate of 39.68% for classifying the ankle pattern in stance, 60.32% for the knee in stance, 20.63% for the ankle in swing and 49.21% for the knee in swing. After learning, the error rates were 39.68% for ankle patterns in stance, 42.86% for the knee in stance, 7.94% of the ankle in swing and 46.03% for the knee in swing. Only a limited number of the conditional probabilities in the CPTs relating primary deficits to gait patterns could be learned.

Discussion

This study was the first to use BN for classifying gait patterns and relating primary deficits to that gait pattern. Error rates for the automatic classification are still quite high but the performance improves after learning and especially when CPTs are not filled out prior to the training phase. Future improvements will be achieved by more expert interviews to fine tune the selection of the relevant GA variables, as well as their quantitative boundaries, and by increasing the number of patients to train the BN.

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Face validity of the GDI in a representative population of children with cerebral palsy

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Summary

The ability of the GDI to distinguish between different GMFCS levels in a representative population of children with CP was demonstrated, lending further weight to the face validity of this instrument.

Conclusions

Averaged GDI data conveys a moderate representation of functional ability in children with CP and as such could be used to make a reasonable estimate of function in this population. Introduction. Numerous methods of describing gait pathology are in use. Some take a clinical approach describing the effect of impairment upon the subject whilst others attempt a more objective analysis using data generated through motion capture. The Gait Deviation Index (GDI) is a relatively new technique which utilizes pattern recognition to determine the extent of gait pathology [1]. In this paper, the ability of the GDI to distinguish between different GMFCS levels and its relationship with gross motor function in children with cerebral palsy (CP) was determined.

Patients/materials and methods

A representative population of 184 ambulant children with CP (unilateral, $n = 94$; bilateral, $n = 90$; age range 4–17 years, mean age 10.8 years) in GMFCS levels I ($n = 57$), II ($n = 91$), III ($n = 22$) and IV ($n = 14$) were recruited to the study [2]. Participants underwent both 3D gait analysis using a six camera Vicon 612 system and a GMFM assessment [3]. Representative gait cycles were jointly selected by a Bioengineer and Physiotherapist experienced in gait analysis. GDI scores were calculated in Matlab using the method and data provided by Schwartz et al. [1] with control data taken from our normative dataset ($n = 96$ limbs; age range 4–18 years; mean age 9.85 years). In order to reflect overall walking capability of the child, left and right leg GDI scores were averaged. Data were analysed using SPSS v.13: A one-way ANOVA with Duncan's post hoc test, as appropriate, determined differences between GMFCS levels. Pearson's correlation coefficient was used to describe the relationship between the GDI and GMFM-66 score.

Results

Valid 3D kinematic and GMFM data were obtained for 147 participants: GMFCS levels I ($n = 53$), II ($n = 71$), III ($n = 17$) and IV ($n = 6$). Results showed significant differences in GDI scores by GMFCS level ($p < 0.001$) with increasing levels of gait deviation in subjects that were less functionally able. Post hoc analysis confirmed significant differences between all adjacent levels. Pearson's correlation

coefficient showed a similar trend, demonstrating a moderate relationship between GDI and GMFM-66 score ($R = 0.69$; $p < 0.001$).

Discussion

The ability of the GDI to distinguish between GMFCS levels concurs with the work of Schwartz et al. [1] who demonstrated its discriminative ability using the Gillette Functional Assessment Questionnaire (FAQ). The averaging of GDI scores may not have been wholly appropriate but, particularly in children with hemiplegia, it was thought more realistic of overall gait function and thus justified in this analysis. The moderate relationship between GDI and GMFM-66 suggests that the subtleties of gait may not be accounted for by gross motor function evaluation alone, whereas gait specific tools such as the GDI encompass both the functional and aesthetic components of walking.

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Muscle strength and kinetic gait pattern in children with bilateral spastic cerebral palsy

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Summary

Children with bilateral spastic cerebral palsy (BSCP) were weaker in all muscle groups in the legs than typically developing children, but gait moments only differed at the ankle. There was a correlation between plantarflexing gait moment and muscle strength in six of eight muscle groups.

Conclusions

Muscle weakness in several muscle groups in the legs affects plantarflexing gait moment.

Introduction

Muscle weakness is recognised as being common in children with BSCP and with a correlation to walking ability [1]. Several authors have described kinematic gait pattern in children with CP, but only a few has presented data on kinetic gait patterns. It was found that the measured muscle strength for a muscle group was 2–5 times higher than moments exerted during walking for the same muscle group in able-bodied children, whereas plantarflexor strength was only just greater than moment during walking [2].

Patients/materials and methods

Twenty children with bilateral spastic BSCP, walking without aids, (15 boy, 5 girls, 9–15 years) and 20 typically developing children (13 boys, 7 girls, 10–15 years) participated. They were all assessed with measurement of muscle strength in eight muscle groups in the legs using a handheld myometer, and a 3-dimensional gait analysis including force data (Fig. 1).

Results

The children with BSCP were significantly weaker in all muscle groups and they walked with slower velocity and shorter stride length when compared with the reference group. Gait moments differed at the ankle level with significantly lower moments in children with BSCP. A ratio between muscle strength and gait moments was calculated showing significant differences compared