6. Discussion

Equipment error is one of the three sources of error that are expected during the routine clinical measurement of static joint angles. This study succeeded at its task of isolating and placing a value on this error when measurements are made with VG. The results show the importance of a correct photographic technique. This study provided a first step towards scientifically examining the potential of VG for measuring static joint angles. Further clinical work is required to complete our understanding of this type of measurement.

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PP-011

Velocity-dependent stability of gait for patients with balance impairments is influenced by biomechanical stabilization

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1. Summary/conclusions

In this study we examined the phenomenon of velocity-dependent stability of gait for neurological patients with balance impairments by combining a clinical experiment and the analysis of a simplified biomechanical model of bipedal locomotion. We present evidence for the hypothesis that the phenomenon likely reflects a combination of context-dependent sensor modulation and fundamental biomechanical properties of human locomotion. The described results are relevant for a detailed understanding of a wide range of movement disorders caused by vestibular and cerebellar diseases as well as cerebral palsy.

2. Introduction

Several recent studies reported that the stability of gait in patients with balance impairments is velocity-dependent. Patients suffering from vestibulopathy or cerebellar ataxia are more stable during running and fast walking than during slow walking [1,2]. To explain this phenomenon, it has been proposed that circuits in spinal cord might take over the control of locomotion for high velocities, inhibiting erroneous vestibular and cerebellar inputs. However, this explanation leaves open why running could be less dependent from balance control than slow walking or how the balance control can be realized by the spinal cord. We propose an alternative explanation that is based on the interplay between context-dependent sensor modulation and biomechanical stabilization of bipedal locomotion.

3. Statement of clinical significance

A detailed understanding of the phenomenon of velocity-dependent stability for patients with movement disorders is relevant for an exact clinical rating and diagnoses of the disorder and is suggested to be helpful for the development of new strategies in physiotherapy.

4. Methods

Clinical experiment: We analysed kinematical data, obtained with a 6-camera VICON motion capture system, from 7 patients with balance impairments (5 suffering from degenerative cerebellar disease, 2 from unilateral vestibulopathy, 1 bilateral vestibulopathy) executing tandem walk with eyes open. In tandem walk, a common task for patients suffering from balance impairments [3], the patient has to place one foot after the other on an imagined line.

Biomechanical model: In order to investigate possible biomechanical influences we studied the velocity-dependent stability of a 3D passive walker, a simplified bipedal model that can walk down a slope without external control [4]. We examined the robustness of this model against lateral disturbances as a function of velocity, providing no lateral control.

5. Results

Clinical experiment: Kinematic analysis of tandem gait reveals less missteps, and significantly decreased lateral sway for higher walking speeds (Fig. 1). The average correlation coefficients r_{av} for lateral sway and speed over 7 subjects, calculated using a Fischer transformation of the individual correlations, are $r_{av} = -0.94$, $p_{av} = 0.0016$ (path-normalized), and $r_{av} = -0.89$, $p_{av} = 0.0069$ (step-normalized). These results show that for a difficult balance task, not the change from walking to running but the gradual increase of velocity lead to better stability.

Biomechanical analysis: To examine the mechanical stability of walking, we perturbed the walker model by tilting

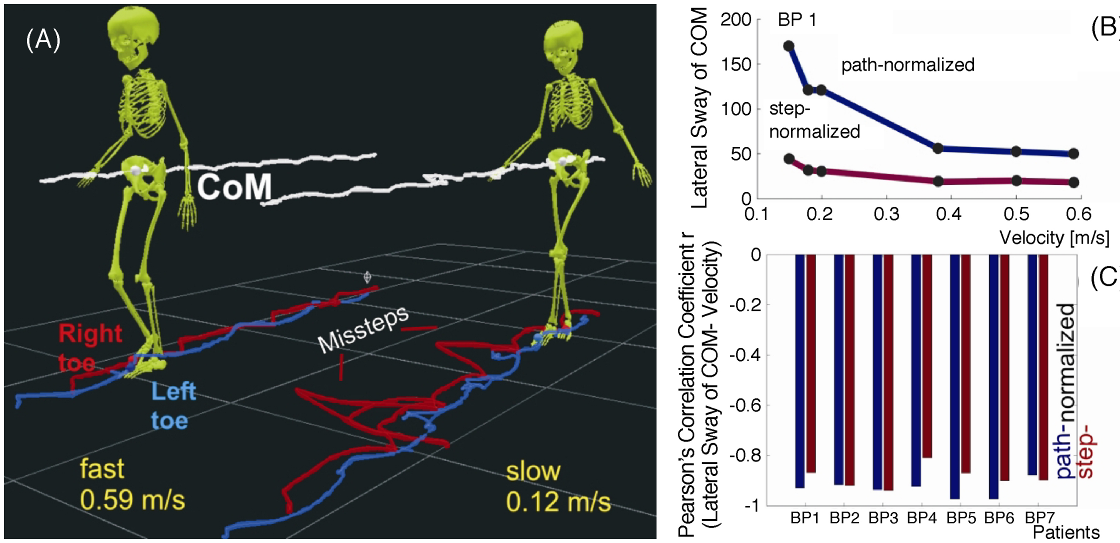

Fig. 1. (A) Motion captured data from cerebellar patient BP1 performing tandem gait. Shown are traces of the Centre of Mass (CoM), and of markers of the right and left toe for slow (0.12 m/s) and fast (0.59 m/s) speed. (B) Normalized measures of lateral sway of the COM plotted against the averaged velocity for patient BP1. (C) Correlations coefficients for all 7 patients.

and pushing it in the lateral direction (resulting in different initial roll angles q_{roll} and roll angle velocities $\dot{q}_{\mathrm{roll}}$). We varied the slope of the supporting plane, that determines the walking speed. For many types of perturbations the walker could be stabilized by increasing the slope of the support plane, i.e. by increasing the gait velocity. This confirms our hypothesis that mechanical stability increases with velocity, independent from control.

6. Discussion

Our study provides evidence for the hypothesis that mechanical stabilization influence strongly the velocity-dependent stability of gait. Therefore, walking with higher velocity or running seems to be less dependent from vestibular information and therefore can controlled to a higher extent by circuits from the spinal cord. Our hypothesis is also consistent with recent studies on healthy subjects showing higher demands of lateral stabilization for slow than for fast walking [4], and an influence of walking speed on the recovery after perturbations [5]. Also for movement disorders not primarily caused by vestibular deficits like cerebral palsy, it is known from clinical practice, that children often seem to run better than they walk [6]. As possible explanation it has been hypothesized that the deviations in the neuromuscular control are better tolerated for running than for walking [7]. The reason for the greater robustness to suboptimal neural control seems to be mechanical stabilization. We conclude that velocity-dependent stabilization is a fundamental property of human locomotion, which likely affects clinical phenomena in a wide range of movement disorders.

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PP-012

Mobile gait analysis—A low-cost solution to provision of this specialised service to a large geographical area

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1. Summary/conclusions

Our centre has developed what is believed to be the World's first truly mobile clinical gait analysis service. This paper reports on the setting up and first year's experience with the mobile gait laboratory. An outreach service is now firmly established in the Mid West and South East of Ireland delivering gait analysis more locally to our patients. This project has resulted in equality of service provision to patients with physical disabilities in our country in terms of gait analy-