Can the use of an auditory feedback device improve the gait pattern of paediatric patients with hemiparesis?

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Introduction

Paediatric spastic hemiparesis is the most common clinical presentation of cerebrovascular accident (stroke) acquired in the paediatric age group. It is a neurologic condition that usually involves cognitive, motor and sensory disabilities [1]. The most prominent disability is loss of motor function, which can cause difficulties in posture, balance and gait control, which can limit daily activities. Quantification of its incidence is difficult, since each of these disorders appears within a wide range of severity. However, patient associations estimate that childhood hemiparesis affects up to 1 child in 1000 [2].

Training with sensory feedback is found to improve mobility-related handicaps in patients with cerebral palsy. For instance, EMG feedback has been used in patients with dynamic equinus deformity [3], and in patients with spastic hemiplegia [4]. Moreover, auditory feedback has had a positive effect on gait symmetry [5], while visual feedback has been used to improve balance training [6].

The aim of this work was to investigate if the use of a new auditory feedback device, based on an inertial measurement unit (IMU), improved the gait pattern of paediatric patients with hemiparesis. For this purpose, three paediatric patients from Hospital Sant Joan de Déu (HSJD) were recruited; and their walking kinematics was analysed before, while and after using that device.

Materials and methods

Three patients from HSJD (aged from 11 to 15) with right spastic hemiparesis were selected for the study (see Table 1), with parental informed consent. Patients 1 and 2 were able to walk without supports, while patient 3 had to wear an ankle-foot support to stabilize gait.

Nine gait trials per patient were captured at the UPC Biomechanics Laboratory: three trials before using the auditory feedback device (natural state), three trials while using the device (feedback state), and three trials after using the device (after feedback state). An initial static capture was also recorded to scale the generic biomechanical model used in the simulation.

The feedback device (Draco Systems, Barcelona, Spain) used an IMU to measure thigh orientation, which is a rough estimation of hip flexion. From this measurement, the physiotherapist selected what kind of auditory feedback would help the patient improve gait. Table 1 indicates the feedbacks used for each patient. Note that the protocol for patient 3 was slightly altered, introducing a second feedback state instead of the after feedback trials.

Table 1: Feedback used in each patient

Patient	Feedback
1	Flexion of 20° on right leg
2	Flexion of 25° on left leg
3	F1: Extension of 0° on right leg F2: Flexion of 20° on right leg

The patients' motion was recorded using a marker-based optical system (NaturalPoint, Corvallis, USA) with 16 infrared cameras sampling at 100 Hz. This system recorded the position of 18 reflective markers attached to the subjects based on the Plug-in Gait marker protocol (Vicon Motion Systems, Oxford, UK) for the lower body.

The biomechanical model used in this work was based on the Gait2392 model provided by OpenSim [7]. It was composed of 11 bodies (pelvis, and right and left femur, tibia, talus, calcaneus, and phalanx bones), and had a total of 18 degrees of freedom: 6 representing the absolute pelvis configuration, and 12 corresponding to relative movements between segments. The model included the 18 markers of the above-mentioned protocol.

After scaling the model with the static trial measurement, inverse kinematics was performed to calculate four angular coordinates in the sagittal plane for all trials: pelvic tilt, hip flexion, knee flexion and ankle dorsiflexion. In order to evaluate changes in gait kinematics, averaged angle patterns during the gait cycle for each state (natural, feedback and after feedback) were calculated; along with maximum and minimum angles, and the range of motion (ROM) for the four studied coordinates. Finally, the root mean squared error (RMSE) was calculated to compare the three patterns among them. Moreover, each pattern was compared to the healthy or standard one.

Results and discussion

The three analysed patients presented different injury severities, thus the effect of the device on the resulting gait differed. Therefore, each patient was analysed independently in this exploratory study.

Regarding patient 1, the most interesting findings were that she gained ROM of the affected hip, while the non-affected one decreased; which can be a form of compensation. She also gained knee ROM for the affected knee and the pattern approached the standard one (Fig. 1). Simultaneously, she presented a stiff knee gait in the natural state, which is compensated with feedback. In after feedback state, she showed hyperextension of the affected knee during stance phase, something that should be prevented, since it is a negative effect.

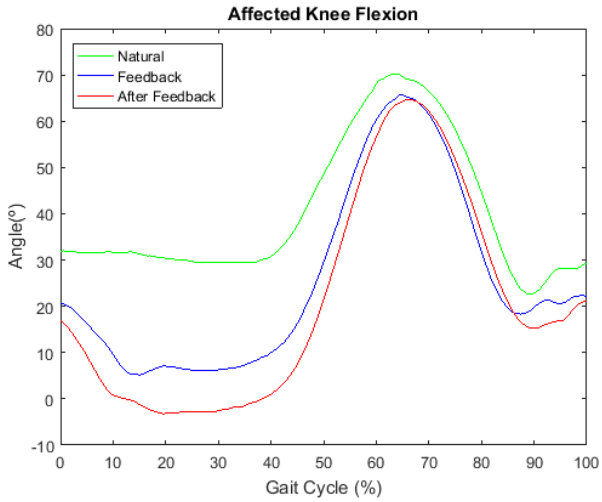

Fig. 1: Affected knee flexion angle during gait for patient 1.

Patient 2 seemed to gain control while walking. The ROM decreased in all four analysed coordinates, which can be concluded as more control over his limbs. The great decrease in the pelvic tilt ROM also showed gain of stability. Fig. 2 shows that the hyperextension that he showed in the non-affected knee in natural gait disappeared with feedback.

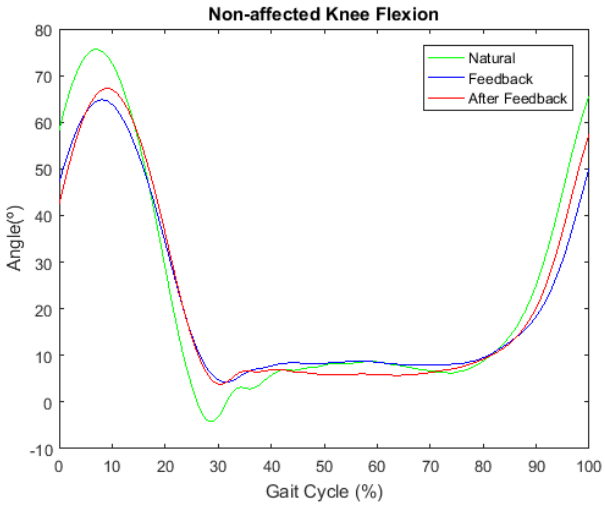

Fig. 2: Non-affected knee flexion during gait for patient 2.

As mentioned before, patient 3 was studied differently due to instability problems. The after feedback state was not measured, while she was set under two feedbacks. In this case, the most interesting finding was that the double peak present in the affected knee flexion during natural gait almost disappeared with both feedbacks. With feedbacks 1 and 2, the pattern of this angle was closer to the standard one (Fig. 3).

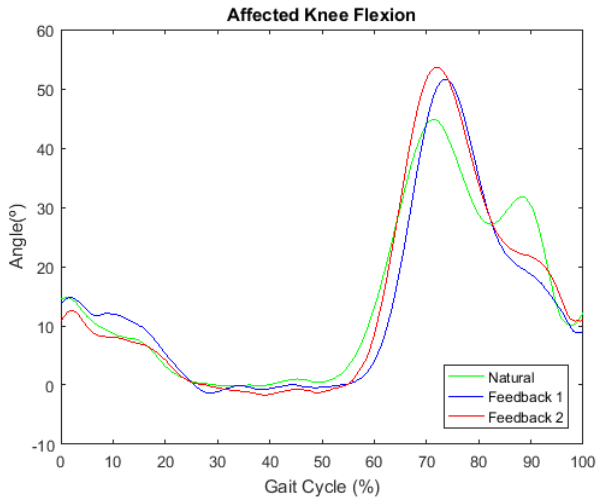

Fig. 3: Affected knee flexion during gait for patient 3.

Conclusion

This exploratory study showed that the use of the auditory feedback device modified the gait pattern of three paediatric patients. However, depending on the patient and the type of feedback used, their natural walking kinematics was altered in different ways. In some aspects, an improvement (i.e., an approach to the healthy or standard gait pattern) was found for the selected subjects.

Nevertheless, a deeper analysis should be done in the future. Bringing more patients to study would give a more general perspective with statistically significant results. Moreover, the timing of the study should be greatly enlarged. Here, the feedback motion capture was taken after the patients had used it for a short time. It would be of more interest if this usage was of months, until the patient is completely adapted to it. The after feedback effects should be then analysed after a stablished time, to see if the patient returns to natural gait or maintains the one learned using the device.

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