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Gait Analysis Using Wearable Sensor Inertial in a Child with CP after Orthopedic Surgery: Case Report

*Paulo Roberto Fonseca Junior**

Department of Rehabilitation Sciences, Universidade Nove de Julho, Brazil

Abstract

Background: Cerebral Palsy (CP) is a permanent disorder of movement and posture, causing activity limitation and gait disturbances. The gait analysis is a useful tool for surgical planning and evaluation of factors associated with pathological gait, rehabilitation and treatment interventions.

Objective: The objective of this study is to evaluate the gait of a patient with cerebral palsy after orthopedic surgery through a wearable inertial sensor, providing quantitative data on walking parameters, addressing the related changes in the gait pattern of the child after orthopedic surgery.

Subjects and Methods: A case study of a 12 year male child diagnosed with spastic cerebral palsy undergoing a gait analysis by wearable inertial sensor in three different moments: before the surgery, after the surgery and after a physical therapy program.

Results: The spatio-temporal parameters found in pre-surgical and post-physiotherapeutic was well within normal ranges for their age and sex. The parameters found immediately after the surgical intervention indicate a decrease in gait quality, which is already expected in the postoperative surgical period.

Conclusion: This study sought to shed a light on the realistic use of the wearable inertial sensor in a clinical setting, and extend the possibility of using portable solutions for gait evaluation in children with CP after orthopedic surgical procedure, providing quantitative data of gait kinematic parameters.

Keywords: Cerebral palsy; Gait analysis; Wearable inertial sensors

Introduction

Cerebral Palsy (CP) is a permanent disorder of movement and posture, causing activity limitation, attributed to non-progressive disorders that occurred in the developing fetal or infant brain [1,2].

Walking is a complex activity and a permanent decision process that can be altered in a variety of neurological pathologies [3]. Changes in mean gait parameters appear universal in all neurological deficits [4], increasing its impact soon after orthopedic surgical interventions. Gait disturbances can lead to impaired mobility, disability, fear of falling or falls, which can result in lower quality of life [3]. The gait abnormalities are mainly caused by spasticity or abnormal muscle tone, decreased motor control and impaired balance. However, because gait abnormalities are primarily caused by spasticity or abnormal muscle tone, often resulting in continued life-course abnormalities if left untreated [5], surgery should be considered in order to improve mobility, the walking potential and quality of life of these patients [3,6]. Throughout an individual's growth, gait abnormalities are compounded by the progressive development of skeletal deformities, soft tissue contractures of musculotendinous units and capsular structures, and dynamic deformities caused by unbalanced abnormal muscle forces [5].

The gait analysis is a useful tool for surgical planning and evaluation of factors associated with pathological gait, rehabilitation and treatment interventions. Although three-dimensional gait analysis provides detailed information on kinematic and kinetic parameters, these systems are limited to laboratory use. In contrast, Inertial Sensor Gait Analysis Systems (ISGAS) facilitate gait analysis in an unobstructed outdoor environment and outside a conventional walking laboratory [7]. Several studies have shown the possibility of using portable and user-friendly solutions, obtaining different types of data acquisition, sharing and information available during the gait, including the kinematics of the individual [8,9].

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***Correspondence:**

Paulo Roberto Fonseca Junior, Department of Rehabilitation Sciences, Universidade Nove de Julho, Rua Padre João Gonçalves, 116-Pinheiros, Sao Paulo, 05432-040, Brazil, Tel: 5511971947326; Fax: 30319659; E-mail: paulofonseca28@gmail.com

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Table 1: Values of spatio-temporal parameters.

Parameter	Pre-surgery	Post-surgery	Post-physiotherapy
Gaitspeed (m/s)	1.62	0.26	1.68
Cadence (steps/min)	109	55.1	108
	Left mean value/ Right mean value	Left mean value/ Right mean value	Left mean value/ Right mean value
Gaitcycleduration (s)	1.13 / 1.13	2.46 / 2.50	1.13 / 1.14
Stridelength (m)	1.81 / 1.83	0.65 / 0.66	1.89 / 1.92
% Stridelenght (% height)	110.4 / 111.5	39.4 / 40.1	115.3 / 116.8
Steplenght (% stridelenght)	50.7 / 49.3	59.8 / 40.2	51.9 / 48.1
Stancephase (% cycle)	52.7 / 62.1	46.4 / 65.8	51.6 / 60.9
Swing phase (% cycle)	47.3 / 37.9	53.6 / 34.2	48.4 / 39.1
First double support phase (% cycle)	7.6 / 6.6	6.8 / 6.3	6.6 / 6.3
Single supportphase (% cycle)	38.5 / 47.7	32.9 / 53.1	39.5 / 48.1

Table 2: Parameters of pelvic angles.

Parameter	Pre-surgery	Post-surgery	Post-physiotherapy
Tiltsymmetry index	44.1	38.1	27.8
Obliquitysymmetry index	87.1	44.1	89.2
Rotationsymmetry index	94.8	53.7	89.2
Range (o)	Left mean value/ Right mean value	Left mean value/ Right mean value	Left mean value/ Right mean value
Tilt	14.9 /16.1	6.9 / 8.2	18.2 / 16.9
Obliquity	3.9 / 4.7	2.9 / 3.6	5.0 / 4.3
Rotation	16.2 / 18.2	5.2/ 5.6	17.7 / 15.5

Due to the optoelectronic system (3D motion capture) restrict the measurement volume to the laboratory and thus may hinder the patient's natural gait, the gait parameters obtained through Clinical Gait Analysis (CGA) are not fully representative of the usual and daily walking habits (described as 'performance') of children with CP. Therefore, there is a need to objectively assess gait performance in daily-life conditions in order to complement CGA, thus enhancing therapeutic choices for children with CP based on real-life data [10].

The aim of this study was to evaluate and compare the related changes in the gait pattern of the child after orthopedic surgery, providing quantitative data on gait parameters in the most appropriate set-up (outside the laboratory environment) for gait assessment of children with CP. Wearable inertial sensor was used to fulfill this need.

Methods

This study was carried out in compliance with the regulating guidelines and norms regulating research involving human subjects stipulated by the National Health Board in October 1996, and it received approval from the Human Research Ethics Committee of University under process number 2.424.085. The patient signed a statement of informed consent declaring that he was aware that the procedure to which he would receive was experimental and free of charge.

A male child diagnosed with spastic cerebral palsy aged 12 years (weight: 48 kg, height: 1.64 m), functionally classified with level GMFCS II, was referred to surgical procedure of bilateral tenotomy of tendon of gastronomies muscles due to increased spasticity in the plantar flexor muscles, causing the child to walk on tiptoes. After the surgical procedure, by medical recommendation, the patient used plaster in the distal lower limbs for one month. The patient performed physiotherapy after the removal of the plaster, by his own physiotherapist, by twelve sessions, three times a week, for four weeks. Each session lasted 60 minutes and the treatment applied to the child was based on conventional techniques, such as stretching, strengthening and proprioceptive training and gait.

The spatio-temporal parameters were obtained with a wireless inertial detection device (G-Sensor®, BTS Bioengineering s.p.a, Italy). This new wearable system based on inertial sensors and a dedicated algorithm for precise and accurate assessment of spatiotemporal gait parameters has been described and validated for gait analysis in children with CP [11,12].

The portable G sensor is a wireless system of inertial sensors for human motion analysis. The sensors are controlled by a data recording unit (up to 16 elements) by a zigbee type radio communication. Each sensor has 62 mm × 36 mm × 16 mm dimensions, weighing 60 g, and consists of a three-axis accelerometer (maximum scale ± 6 g), a 3-axis gyroscope (full scale ± 300°/s), and a magnetometer of 3 axes (full scale ± 6 Gauss). This device is calibrated with acceleration of gravity immediately after manufacture. For this work, only one device was used that collected the data at a sampling frequency of 50 Hz.

The gait analysis was performed in hospital and clinic environment, pre and postoperative (after 1 month) and after 4 weeks of physiotherapy, with the child walking a single time along a 15 m corridor at a self-selected speed and way more natural. In order for the device to acquire gait values it was necessary for the patient to perform 5 full gait cycles of gait on each leg to be recorded. The distinction of the right and left legs was recorded through the oscillations of accelerometers, gyroscopes and magnetometers during the gait analysis. The inertial sensor was attached in the lower lumbar level (covering the L4-L5 inter-vertebral space) with a semi-elastic neoprene belt. The device acquired acceleration values (along three orthogonal axes: anteroposterior, mid-lateral and super-inferior) that were transmitted in real time by bluetooth to a PC and processed with dedicated software (BTS Bioengineering G-Studio®) to derive the following parameters:

1. Step length: distance between two consecutive heel contacts of the same foot (m);

2. Running speed: average instantaneous speed within the running cycle (m s-1);

3. Cadence: number of steps per minute (min-1 steps);

4. Position and duration of the balance phase: expressed as a percentage of the gait cycle, representing the ratio of a gait cycle involving foot support (from the heel to the foot with the same foot) and balance of the lower limb;

5. Duration of the double support: the duration of the support phase in both feet, expressed as a percentage of the walking cycle.

6. Pelvic angulation (inclination, obliquity and rotation).

Results

The results of the experimental tests are summarized in Tables 1 and 2.

Discussion

In this study, we investigated the related changes in the gait pattern of the child after orthopedic surgery using an inertial sensor. The spatio-temporal parameters found in pre-surgical and post-physiotherapeutic wasn't well within normal ranges for their age and sex [13]. The small variation between the left and right mean values probably occurred due to the asymmetry of the lower limbs found in the patient during his inspection (left leg 89 cm, right leg 86 cm). However, this may lead to further investigation of each experiment on foot to find out the source of variation. The spatio-temporal parameters found immediately after the surgical intervention indicate a decrease in gait quality, which is already expected in the postoperative surgical period [14].

The displacements for tilt, obliquity and pelvic rotation and range of motion were maintained with minimal variations in relation to pelvic obliquity. The greatest variations were found in the pelvic tilt and rotation displacements (Table 2).

The treatment of the child with cerebral palsy should be performed by a multidisciplinary team. The orthopedist and physiotherapist are responsible for preventing and correcting lower limb deformities, contributing to the patient being as independent as possible in his Activities of Daily Living (ADL) and in his locomotion. The results showed that walking ability was not improved after surgery and rehabilitation compared to the preoperative situation. From our point of view, this study may demonstrate the need for the follow-up of physical therapy after the orthopedic surgical procedure for a long-term period. Assisting the patient in establishing motor control in the new biomechanical alignment provided by the surgical procedure and promoting better physical fitness are major goals of postoperative physical therapy [15].

The inertial sensor gait analysis has been shown to be a useful tool for rehabilitation and treatment interventions, detecting some measures of relevant results, such as kinematic parameters and functional alterations, which are insufficient at conventional physical examination. Some limitations of this study should be recognized: since we wanted to replicate a realistic use of the inertial sensor in a outside the laboratory environment setting, and extend the possibility of using portable and user-friendly solutions, obtaining different types of data acquisition, we recruited only one patient before, during and after their surgical intervention and physiotherapeutic. Second, the study evaluated only general gait parameters. It would have been interesting to discuss kinematics of the knee and ankle (since the surgery was a tenotomy of the gastronomies tendon), but it was not possible to detect these kinematic parameters with the device used by this study. Future studies should investigate larger groups of patients with the same disability, providing more detailed information on kinematic gait parameters in these individuals.

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