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# The effect of hydrotherapy treatment on gait characteristics of hereditary spastic paraparesis patients

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ABSTRACT

*Background:* Hereditary spastic paraparesis (HSP) is a group of neurological disorders characterised by slowly progressive increasing muscle tone, predominantly in the lower limbs, with relatively preserved power. This leads to progressive difficulties in motor control and walking.
*Objective:* The purpose of this study was to evaluate the effectiveness of hydrotherapy treatment when used as a means to increase locomotor function in individuals with late onset HSP. This paper discusses the analysis of the effect on gait characteristics.
*Methods:* Nine people with HSP were asked to participate in pre- and post-hydrotherapy gait analyses. Ground reaction force and motion trajectories were recorded and used to calculate spatiotemporal gait parameters, joint angles and moments.
*Results:* The normalised joint kinematics and kinetics profile revealed that the biomechanics of people with HSP were similar to that of controls for most of the joints, but with lower range of motion. Walking speed increased significantly (11%) after the course of hydrotherapy. Though part of this was achieved through increased ROM there was also a further increase in hip internal rotation and in peak hip extension moment.
*Conclusions:* Although participants had increased walking speed and step length, it appears that hydrotherapy increases the ability to perform compensatory strategies rather than resulting in a more typical kinematic and kinetic approach.



## 1. Introduction

Hereditary spastic paraparesis (HSP) is a group of neurological disorders characterised by slowly progressive increasing muscle tone, predominantly in the lower limbs, with relatively preserved power. This leads to difficulties in walking. As qualitative clinical observation cannot adequately describe joint kinematic and kinetic parameters [1], three-dimensional gait analysis has been proposed for quantifying progression of hereditary spastic paraparesis and the effect of therapeutic interventions. A small number of studies have used gait analysis to evaluate spatiotemporal and kinematic parameters [1–5]. Piccinini et al. [5] reported knee, ankle and hip joint kinematics and kinetics in the sagittal plane during walking for nine children with HSP and 15 healthy children. They found that children with HSP generally presented with a higher peak knee flexor moment and a lower peak ankle plantarflexor moment than healthy children. Marsden et al. [3], found patients with HSP tended to exhibit a stiff legged walk characterised by a lesser degree of knee flexion during swing phase. Only one study has used quantitative motion analysis both before and after a therapeutic intervention to evaluate outcomes: Molteni et al. [4] analysed gait characteristics for one single patient with HSP (31-year-old male) for a follow-up period of 2 years concurrent with intrathecal baclofen therapy. Our study presents the results of gait analysis of nine participants pre- and post-hydrotherapy treatment.

The purpose of this study was to evaluate the effect of hydrotherapy treatment in individuals with late onset HSP by quantifying gait parameters in adults with HSP. Hydrotherapy is one of the oldest therapeutic methods for managing physical dysfunctions [6–10]. It is used for its beneficial effects on body tissues including heating, cooling, debridement, pain relief, muscle relaxation, treatment of joint stiffness, psychological relaxation, and warm-up to assist with exercise. The supportive, assistive, and resistive qualities of the water make it possible for patients to

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perform range-of-motion, strength, and endurance exercise [6,7,11]. Studies have shown that hydrotherapy induces positive changes in muscular strength, fatigue, work and power when comparing pre- and post-therapy in patients presenting with increased muscle tone as a result of multiple sclerosis [8,12], spinal cord injury [9] and stroke [10]. However, it has not previously been studied in people diagnosed with HSP. It is a conservative treatment that has widespread availability.

## 2. Methods

### 2.1. Participants

Patients with HSP were recruited from the Auckland City Hospital Neurogenetics Clinic. All participants provided written informed consent and the study was approved by the Northern X Regional Human Research Ethics committee of New Zealand. A database of control participants was also used for comparison. These participants provided informed consent approved by the University of Auckland Human Participant Ethics Committee.

### 2.2. Data collection

Spasticity (adductors, knee flexors, knee extensors, plantarflexors) was measured using the Modified Ashworth Scale [13] by a single observer, a physiotherapist trained and familiar with the scale. Gait analysis was conducted at the Biomechanics Laboratory in the Department of Sport and Exercise Science at the University of Auckland. Gait analysis parameters were analysed in three domains: spatiotemporal, kinematics and kinetics.

Each participant underwent a biomechanics analysis, followed by a 10-week hydrotherapy programme. Although tailored to the individual participants, this programme started with a group hydrotherapy session (two small groups) followed by five weeks of individual hydrotherapy twice per week, another group session and an additional five weeks of individual exercise. Each session was 45-min in length. The hydrotherapy was followed by a final biomechanics analysis.

### 2.3. Gait data acquisition

To record participants' motion, spherical reflective markers of diameter 14 mm were attached to each participant by adhesive, double-sided tape. The standard Cleveland Clinic marker set was used such that markers were placed on each shoulder at the acromio-clavicular joints, elbows and wrists, triceps, sacrum, left and right anterior iliac spines, thigh triads, lateral and medial epicondyles of the knee, shank triads, lateral and medial malleoli of the ankle, calcaneous at the heels, and the second metatarsal on both feet [14]. A high speed infrared camera system (Vicon Oxford Metrics, Oxford, UK) was used to capture the position of the passive optical markers attached to each participant's skin in 3-dimensional space. Ground reaction forces were measured by two Bertec force plates (Bertec Corporation, Ohio, USA).

Each participant performed a static calibration trial to locate anatomical landmarks and estimate the location of the joint centres for each segment. A trial consisted of walking along a 10-m track across the force plates at a self-selected walking speed with shoes on. At the end of the track, the participant turned around and walked across the force plates in the opposite direction constituting another trial. This allowed the participants to keep a steady pace rather than requiring them to stop and start. Kinematic data was collected at a frequency of 100 Hz, while ground reaction forces were measured at a sampling rate of 1000 Hz. Trials were performed until between three and five successful trials were achieved per patient. A successful trial included a full foot placement on one force platform with clear marker visibility of all markers throughout the trial. A full gait cycle was defined as both the ipsilateral and contralateral foot on and foot off as defined by the vertical reaction force and zero acceleration in both the vertical and horizontal direction. As one of the force plates became damaged during the pre-intervention test, only 5 participants' force plate data were collected during the initial analysis.

### 2.4. Data processing

Marker coordinate data were low-pass filtered with a cut-off frequency of 6 Hz using a fourth-order Butterworth filter. Based on measured kinematic and force data, spatiotemporal gait parameters were generated using Vicon Workstation Software (Oxford Metrics, Oxford, UK). Each marker's position data was entered into the Cleveland Clinic Biomechanical Model to determine joint centre positions and joint angles [14]. This marker set has been shown to have less variability in the transverse plane than the Helen Heyes marker set [14] and has been validated in our laboratory for individuals with motor control impairments [15]. Differentiation of the position data allowed for the calculation of velocity and acceleration. Combining all kinematic data and ground reaction force data, an inverse dynamic analysis procedure [10] was developed to calculate the reactive forces and moments at all joints (ankle, knee, and hip). In this procedure, each body segment was considered as a rigid body and the body segments were thought to be interconnected as a kinematic chain. The inertial parameters of the segments were calculated based on the participant's height and weight using standard biomechanical procedures [16].

### 2.5. Statistics

One-way analyses of variance with repeated measures were performed to compare spatiotemporal, kinematic and kinetic parameters between pre- and post-hydrotherapy. The Shapiro–Wilk test was performed to test the normality of the data. The level of statistical significance was set at equal to 0.05 for all tests.

Quantitative gait observations were compared with historical control data from 7 healthy volunteers collected by the biomechanics department.

## 3. Results

Eleven participants with HSP were recruited. One person dropped out as a result of pneumonia which prevented him from attending hydrotherapy sessions, another could not be contacted for final evaluation. One participant started oral baclofen just prior to starting hydrotherapy sessions (at the time of the study he was just taking one 10 mg tablet a day as he had not been able to tolerate higher doses). Other participants did not change their medical treatment during the course of the trial.

### 3.1. Clinical examination

No participants exhibited spasticity greater than 1 on the Modified Ashworth Scale (MAS), i.e. the increase in tone was manifest at most by a catch and release or by minimal resistance at the end of the range of motion when the affected part was moved in flexion or extension [13]. Two participants exhibited a spasticity level of MAS = 1 in adductors, knee flexors, knee extensors, and plantarflexors. Six of the remaining seven had bilateral spasticity in the right ankle plantarflexors (all MAS = 1).

### 3.2. Spatio-temporal parameters

The spatio-temporal parameters of the gait cycle pre- and post-hydrotherapy are shown in Table 1. There was a significant 11% increase in walking speed after hydrotherapy (0.85 m/s pre to 0.94 m/s post, $p < 0.05$). Only one participant decreased in walking speed (by 0.03 ± 0.025 m/s) while two stayed the same and the remaining six improved. There was also a trend towards greater step length ($p < 0.07$).

### 3.3. Three dimensional gait analysis

Tables 2 and 3 show the mean values of all gait parameters in the study both pre- and post-hydrotherapy treatment.