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Gait adaptability training improves obstacle avoidance and dynamic stability in patients with cerebellar degeneration

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ABSTRACT

Balance and gait problems in patients with cerebellar degeneration lead to reduced mobility, loss of independence, and frequent falls. It is currently unclear, however, whether balance and gait capacities can be improved by training in this group of patients. Therefore, the aim of this study was to examine the effects of gait adaptability training on obstacle avoidance and dynamic stability during adaptive gait. Ten patients with degenerative cerebellar ataxia received 10 protocolized gait adaptability training sessions of 1 h each during 5 weeks. Training was performed on a treadmill with visual stepping targets and obstacles projected on the belt's surface. As the primary outcome, we used an obstacle avoidance task while walking on a treadmill. We determined avoidance success rates, as well as dynamic stability during the avoidance manoeuvre. Clinical ratings included the scale for the assessment of ataxia (SARA), 10 m walking test, timed up-and-go test, berg balance scale, and the obstacle subtask of the emory functional ambulation profile (EFAP). Following the intervention, success rates on the obstacle avoidance task had significantly improved compared to pre-intervention. For successful avoidance, participants allowed themselves smaller stability margins in the sagittal plane in the (shortened) pre-crossing step. However, in the subsequent steps they returned to baseline stability values more effectively than before training. SARA scores and the EFAP obstacle subtask improved significantly as well. This pilot study provides preliminary evidence of a beneficial effect of gait adaptability training on obstacle avoidance capacity and dynamic stability in patients with cerebellar degeneration.

1. Introduction

Degenerative cerebellar ataxias are characterized by progressive disturbances in coordination, balance, and gait. Patients show an increased postural sway during stance and walking, which is omnidirectional, but greatest in anterior–posterior direction [1,2]. Safe ambulation requires the ability to make gait adjustments dependent on environmental demands, such as stepping over uneven tiles. These step adjustments require a longer single leg stance phase. During avoidance of obstacles however, lateral instability is reported to be higher in ataxia patients due to a longer single-leg phase and simultaneous counter phase trunk movements, which are essential for obstacle crossing [2,3]. All these factors contribute to a high risk of falling, with an incidence of falls up to 93% per year in patients with cerebellar degeneration, often accompanied with injuries and limitations in activities of daily living [4].

There are no pharmacologic treatments available at this moment that can provide sufficient symptomatic relief. As a result, physiotherapeutic interventions play an important role in the management of degenerative cerebellar ataxias, with improvements of balance, physical condition, and gait as main training goals [5]. As the cerebellum functions as a primary site for adaptation of limb movements and dynamic regulation of balance, and cerebellar patients are also known to have deficits in motor learning [6–8], the potential effectiveness of balance and gait training can be questioned. However, there is evidence of

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adaptation, functional motor retraining, and motor learning after cerebellar damage [9–11]. In addition, other studies suggest potential beneficial effects of physiotherapeutic interventions on balance, gait, upper limb functioning, and ataxia severity [5].

Since adjustment of gait patterns to the variable requirements of the environment is essential in daily life, gait adaptability training might be useful in improving walking and avoiding falls. This training modality has been reported to improve obstacle avoidance abilities and to reduce fall rates in healthy elderly. It was also found to ameliorate walking speed, step adjustments and balance in patients with stroke [12–15]. The aim of this study was to examine the effects of gait adaptability training on an instrumented treadmill with visual cues on obstacle avoidance and dynamic stability in patients with degenerative cerebellar ataxia. We hypothesized that training would improve the participants' ability to avoid sudden (physical) obstacles during walking on a treadmill, as well as dynamic stability during the obstacle crossing steps. We also expected these improvements to translate to better performance on a clinical overground walking test involving obstacle avoidance.

2. Methods

2.1. Subjects

We recruited ten male patients (age 61.4 ± 5.7 years, disease duration 8.5 ± 7.3 years) from the Department of Neurology of the Radboud University Nijmegen Medical Centre, seven diagnosed with sporadic adult-onset ataxia (SAOA), two patients with spinocerebellar ataxia type 6 (SCA6), and one with spinocerebellar ataxia type 3 (SCA3). Patients were included if they were diagnosed with degenerative cerebellar ataxia and no other causes for their symptoms were found. Exclusion criteria were the use of walking aids, presence of visual impairments, other disorders influencing walking, interfering cognitive impairments, and the use of medication which may influence balance, walking or cognition. Inclusion and exclusion criteria were re-checked during an intake visit by means of a standardized medical history and neurological examination. At this intake visit, participants also completed a familiarization session with the obstacle avoidance task.

Participants did not receive other training aimed at improvement of balance or gait during the study period. All participants gave written informed consent and approval was obtained from the local medical ethics committee.

2.2. Intervention

The participants received 10 protocolized training sessions of 1 h each over a period of 5 weeks, which were supervised by the same physical therapist (JDB). Training was performed on a treadmill instrumented to project visual cues on the belt, such as obstacles and stepping targets (C-mill, Forcelink BV, Culemborg, The Netherlands) [16] (Fig. 1). The embedded force platform provided detection and feedback of several gait parameters, which were also used to adjust the timing of visual context to participant's gait [17]. Each training session consisted of 6 blocks of gait adaptability exercises (see Appendix I). During training, participants walked at a comfortable speed (as assessed in training sessions 1, 2, and 6), without using the handrails. The level of difficulty was adapted to the participant's abilities and was gradually increased to keep the training challenging.

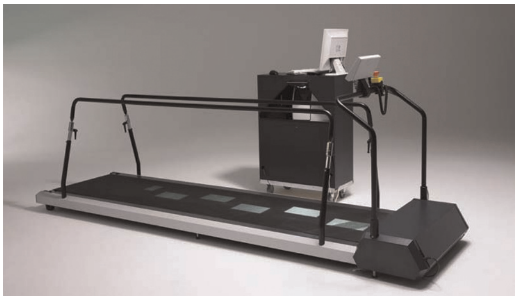

Fig. 1. The C-mill.

2.3. Pre- and post-intervention measurements

To evaluate the effects of training, the outcome measures were assessed a week before the first training (pre-intervention) and one week after the last training (post-intervention). Participants performed a standardized instrumented obstacle avoidance task while walking on a treadmill [12], and several clinical tests were done (see below).

The obstacle avoidance task involved 30 obstacles (during two series of 15 trials), while walking on a treadmill (width 1.25 m [*w*]) at a fixed velocity of 2 or 3 km/hr, depending on the participant's abilities. A wooden obstacle (40 cm [*l*] × 30 cm [*w*] × 1.5 cm [*h*]) was held by an electromagnet, just above the walking surface in front of the non-dominant foot at a distance of approximately 10 cm from the most anterior position reached by the toes. Reflective markers attached to the feet, legs and trunk were recorded by a 6-camera 3D motion analysis system (Vicon, Oxford Metrics, London, UK) and were processed in real time. Based on the timing of heel strikes, a computer program (Matlab, version 2011a, The Math Works Inc., Natick) triggered the obstacle to be released at different, pre-set moments in the step cycle, which were unpredictable for the participants. Contact with the obstacle, stepping to the side, or holding on to the safety bar were defined as a failure to avoid the obstacle. Participants wore a safety harness attached to the ceiling, and their own comfortable low-heeled shoes.

The clinical tests used were the scale for the assessment of ataxia (SARA) [18], the 10 m walking test (10MWT, comfortable and fast speed) [19], the timed up-and-go test (TUG) [20], the berg balance scale (BBS) [21], and the obstacle subtask of the emory functional ambulation profile (EFAP) [22]. To assess participants' level of confidence in balance, we used the short version of the activities specific balance scale (ABC) [23]. Participants had to indicate on a questionnaire whether they had experienced falls in the six weeks prior to the pre-intervention and prior to the post-intervention measurements. Another purpose designed questionnaire was used to evaluate their experiences with the training.

2.4. Data analysis

Obstacle avoidance scores were noted during the experiment and verified post hoc based on video recordings and 3D-marker data. To determine the difficulty level, for each trial the available response time (ART) was calculated, defined as the time span between the instant of obstacle release, and the moment when the toes would have passed the front of the obstacle if no alteration of the stride had been made. The ART was calculated by extrapolating the walking pattern of the previous steps. Trials in which the ART was too short (<0.15 s; virtually impossible to succeed), or too long (>0.75 s; hardly any gait adjustment required), were excluded from further analysis [24]. Obstacle avoidance success rates were calculated as the percentage of successful trials of the included trials. Step width and centre of mass excursions (CoM) were extracted from the 3D-marker data. Step width was defined as the distance between the malleolus markers of each foot, corrected for the marker diameter. In addition, the extrapolated centre of mass (XCoM) was calculated, which corrects the centre of mass for its