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LETTER TO THE EDITORS

Long-term effect of robot-assisted treadmill walking reduces freezing of gait in Parkinson's disease patients: a pilot study

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Dear Sirs,

Freezing of gait (FOG) is a common and disabling symptom in patients with advanced Parkinson's disease (PD). Treatment options are often limited, since dopaminergic medication can either alleviate or aggravate FOG, and deep brain stimulation does not seem to suppress FOG as well as other PD symptoms [5]. In the last decade, physiotherapeutic studies moved into the focus of research. Two case studies found that repetitive robot-assisted treadmill training reduces FOG [4, 10], and in a randomized controlled trial robot-assisted gait training was superior to conventional physiotherapy on general walking performance in PD patients [6]. However, long-term effects of this potentially new training method are unknown so far. Based on previous studies, we hypothesised that robot-assisted treadmill training specifically reduces FOG by either increasing step length and/or decreasing step length variation, and that, similar to other physiotherapeutic training methods, this therapeutic effect declines over time after cessation of training.

Three PD patients diagnosed according to the UK PDS Brain Bank Criteria with severe FOG participated in the study. All patients gave informed consent before study participation. The study was approved by the local ethics committee. Patients were trained by an experienced physiotherapist (FC) specialized in neurological rehabilitation. All patients received 10–12 training sessions of 30 min on a robot-assisted treadmill (Lokomat®, Hocoma, Switzerland) in their regular medication ON.

Robot-assisted treadmill walking includes treadmill walking combined with a certain degree of body weight support through assistance of mechanically driven robotic orthosis. A robotic exoskeleton attached to the patients' legs shifts them passively through a stereotyped gait cycle over a treadmill with variable amounts of assistance. Walking parameters such as gait speed, leg movement assistance and body weight support can be adjusted individually. All patients received a piloting training session before the actual training started. We intended to use the same walking parameters for all three patients. All three patients reported comfortable training with a gait velocity of 1.5 km/h, fully assisted leg movements and a body weight support of 70 %. In the training session, body weight support was initially set at 100 % and was then gradually reduced to 70 % to familiarize patients with the walking device. Range of motion at the hip joint was set at 45°; all other settings were kept according to the manufacturer's specifications.

On some occasions, training sessions had to be terminated due to exhaustion shortly before 30 min were

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achieved (patient 1 first session only 20 min, third session only 25 min; patient 2 first, third and seventh session only 20 min; patient 3 first session only 15 min, second and fifth session only 21 min). Pre-interventional assessment included clinical characteristics (disease duration, MMSE, UPDRS I, II and IV), motor score (UPDRS III videotaped and evaluated by a MDS-certified rater [MB] blinded for date of assessment, i.e., before or after training) and objective gait analysis using the Leonardo Gangway Mechanograph [11]. As rigidity can not be rated on video, a rigidity rating could not be performed in a blinded manner. Three gangway measurements were performed, and the mean was used for further analysis (patient 2 could only perform one trial before the training due to exhaustion). FOGQ was completed before and after the intervention, and also after a 6 week follow-up for evaluation of long-term effects. The training and the gait evaluations were performed under patients' regular medication, which was not changed

Table 1 Patient characteristics and FOGQ and UPDRS scores before and after training and at 6 week follow-up (only FOGQ scores)

			Patient 1			Patient 2			Patient 3
Sex			M			M			F
Age (years)			62			69			61
Years of disease			10			7			6
H&Y score			3			4			1.5
MMSE			30			26			30
Dominance type			a/r			a/r			a/r
LEDD (mg)			900			1,500			1,100
	Before training	After training	Follow-up	Before training	After training	Follow-up	Before training	After training	Follow-up
FOGQ	13	9	13	20	14	18	13	8	11
FOGQ #3	2	2	2	4	3	3	3	2	2
UPDRS I	1	2	–	5	3	–	3	3	–
UPDRS II	17	16	–	29	22	–	12	7	–
UPDRS II item 14	2	1	–	3	2	–	3	1	–
UPDRS III	38	35	–	40	35	–	15	11	–
UPDRS IV	2	2	–	2	2	–	5	1	–

H&Y Hoehn and Yahr score, *MMSE* mini mental state exam, *LEDD* levodopa equivalent daily dose, *FOGQ* freezing of gait questionnaire, *FOGQ #3* FOGQ item 3, *UPDRS* unified Parkinson disease rating scale, *a/r* akinetic-rigid

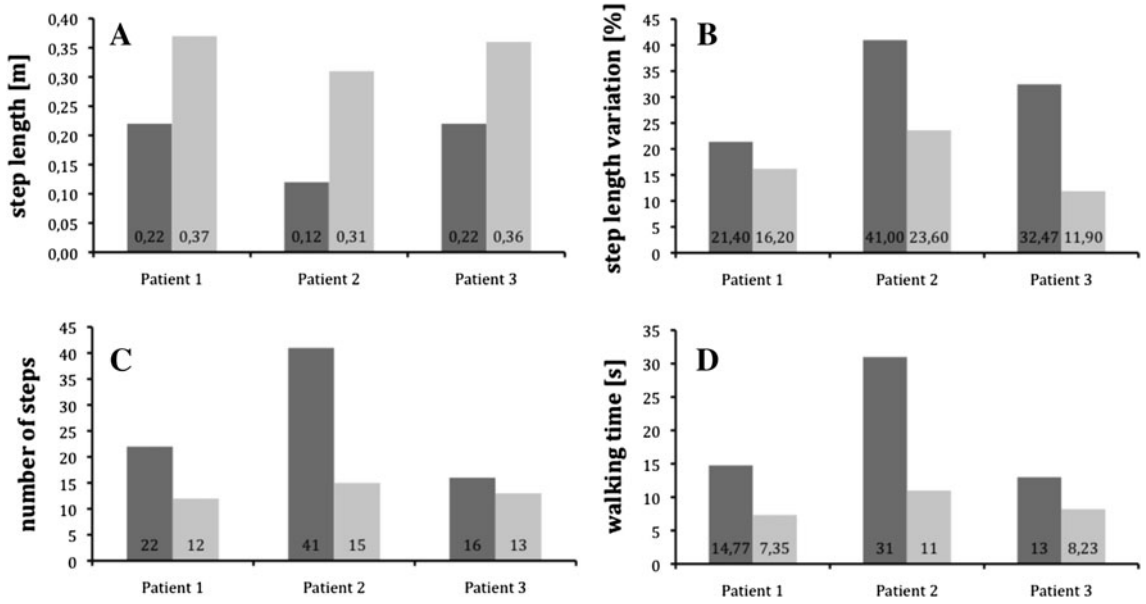

Fig. 1 Gait analysis via ground reaction forces. Step length (**a**), step length variation (**b**), number of steps (**c**), and walking time (**d**) for each patient are shown before and after training

during the study. Patients were tested and trained approximately 1 h after medication intake in a stable ON condition at the same time of the day (patient 1: 4 pm, patient 2: 5 pm, and patient 3: 6 pm).

After the intervention, FOG improved in all patients measured by FOGQ. This effect essentially faded at the 6 week follow-up (Table 1). UPDRS I, II, III and IV scores were only mildly affected by the training. Gait analysis revealed an increase of step length (Fig. 1a) and a decrease in step length variation (Fig. 1b). Number of steps (Fig. 1c) and walking time needed to complete the gangway (6 m) were reduced after the training (Fig. 1d).

This pilot study is in line with two previous case studies [4, 10] which support the idea that robot-assisted treadmill walking can improve FOG. FOGQ scores of all three patients decreased in our pilot study. Gait analysis revealed a step length increase and a decrease in step variation in all patients as shown by [4, 10]. As expected, UPDRS III scores were only mildly affected after gait training. Our study is limited due to the low number of patients and the lack of a control group. Also, the utility of the FOGQ as an indicator of the training effect was called into question [8]. An additional walking test, maybe with provocation manoeuvres before and after training, could have given additional information on occurrence and duration of FOG episodes. However, as FOG often occurs at home and not in the clinic, we on purpose decided to measure FOG on a self report scale comprising a period of time rather than a specific time point as a walking test would do.

Why does robot-assisted treadmill-walking ameliorate FOG? One explanation would be that larger steps, as induced by robot-assisted training, reduce and smaller steps increase the occurrence of FOG [2]. Another explanation could be that increased step-length variation, which is altered in PD patients with FOG even between FOG episodes, is restored by the training [7]. Also, it can not be excluded that cueing through the treadmill elicits the observed effect and not the robot assistance per se. Positive sensory or visual feedback is known to be a key feature for physical therapy in PD patients suffering from FOG [3, 9]. In line with this explanation, Carda et al. [1] found that robotic gait training is not superior to treadmill training alone; however, FOG was not assessed specifically in this study. Last, the observed improvement of FOG could merely be a placebo effect due to increased attention through the physiotherapist or the impressive appearance of the training robot.

Future studies with a higher number of patients and comparison with control training will shed light into the exact therapeutic mechanisms (cueing, reduction of step length variation, increase of step length or placebo) underlying this potentially new training method. The long term effect presented in our study demonstrates that the therapeutic effect fades over time. A continuous training is important, if this costly device is integrated in future therapeutic paradigms.

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Conflicts of interest The authors report no conflict of interest. All authors have no affiliation and have received no financial or in kind support from the manufacturers of the equipment used in this study.

Ethical standard All human studies must state that they have been approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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