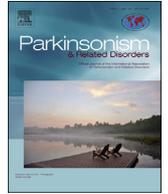




Contents lists available at ScienceDirect

Parkinsonism and Related Disorders

journal homepage: www.elsevier.com/locate/parkreldis

Sensor assisted self-management in Parkinson's disease: A feasibility study of ambulatory posture detection and feedback to treat stooped posture

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ARTICLE INFO

Article history:

Received 15 July 2017

Accepted 24 July 2017

Keywords:

Parkinson's disease

Self-management

Rehabilitation

Stooped posture

Sensor

Ambulatory

Cueing

ABSTRACT

Introduction: A stooped posture is one of the characteristic motor symptoms of patients with Parkinson's disease, and has been linked to impairments in daily activities and quality of life. We aimed to test the efficacy, safety, practical utility and user-friendliness of a posture correction and vibrotactile trunk angle feedback device (the UpRight) in the home setting of patients with Parkinson's disease with a stooped posture. It was hypothesized that ambulatory use of the UpRight would be safe, feasible and result in a less stooped posture, i.e. a lower trunk angle during daily activities.

Methods: 15 patients wore the UpRight during a baseline period of 1 week (no feedback), followed by an intervention period of 1 week (feedback).

Results: We found a significant decrease (average -5.4°) in trunk angle from baseline period to intervention period without the occurrence of adverse events. In addition, patients found the device usable and beneficial to posture.

Conclusion: Use of the feedback and correction device has a positive effect on ambulatory trunk angles. The device appears to be both safe and useful for self-management of stooped posture in patients with Parkinson's Disease.

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1. Introduction

Stooped posture, an abnormally forward bent position of the trunk and head, is one of the characteristic and common motor symptoms of Parkinson's disease (PD) [1,2], affecting up to 73% of patients [3]. Stooped posture is relatively resistant to dopamine replacement therapy (DRT) and deep brain stimulation (DBS) when compared to distal motor signs such as tremor or bradykinesia [4] and the underlying causes are under-investigated [5].

Stooped posture can impair the patients' balance, ability to walk and performance of daily activities, thereby significantly impacting quality of life [2,6–9]. Early detection and correction of postural abnormalities is important to prevent irreversible deformities and accompanying complications of advanced camptocormia (shortness of breath, difficulty swallowing, radiculopathy, visual

disruption, and pain) [5].

Non-drug rehabilitative therapies like physical therapy can improve postural flexibility and postural stability with physical exercises [6,10], or by compensating for motor impairments such as freezing of gait by using single visual cues [11] or rhythmic sensory cues [12,13]. While postural instability and walking disability has been widely studied in Parkinson's patients, there are few studies that have targeted stooped posture in patients with PD [2,7].

One of the disadvantages of existing rehabilitative therapy programs is that they are mostly applied and evaluated in an outpatient clinical setting. During standardized therapy sessions patients are typically able to restore their stooped posture temporarily when focused attention is requested [14], but in daily life patients are generally not consciously aware of bent posture [5] and stooping worsens. In addition, transfer of outpatient training strategies may be limited. One way of coping with these drawbacks is to use an ambulatory device in the home situation, in addition to the regular exercise therapy. Such a device can monitor and give immediate feedback of the posture so that it can be corrected

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immediately by the patient to promote self-management. Such a posture feedback and correction device (“UpRight”) was co-developed by a researcher from VU University Medical Centre (VUmc) and 2M Engineering Ltd in the Netherlands (www.2mel.nl/) and provides a vibrotactile cue when the trunk angle exceeds a threshold value to gain the attention of the patient, triggering an active correction of the stooped posture. However, while such an approach has face validity, its efficacy, practical utility, safety and user-friendliness remains to be determined.

The main objective of this pilot study was therefore to test the efficacy, practical utility and user-friendliness of the UpRight in the home setting of patients with PD with a stooped posture. It was hypothesized that ambulatory use of the UpRight would be safe, feasible and result in a less stooped posture, i.e. a lower trunk angles during daily activities.

2. Methods

2.1. Study population

15 patients with idiopathic PD were recruited from the neurology outpatient clinic of VUmc. All patients gave their written consent to participate and met the following inclusion criteria: (a) diagnosed with idiopathic PD; (b) Hoehn & Yahr stage 1–3; (c) stooped posture as major motor symptom, indicated by a score ≥ 2 on item 28 from the Unified Parkinson's Disease Rating Scale (UPDRS); (d) postural abnormality which can be actively corrected as assessed by a physical therapist; (e) sufficient cognitive function, confirmed by a neurologist; (f) absence of relevant co morbidities; (g) stable medication regimen. All patients provided written informed consent. The study was approved by the ethical committee of the VUmc (NL31556.029.100).

2.2. Design and procedures

Study methodology was that of a multiple case control pre-post design (AB) with a baseline period (A) followed by an intervention period (B), where the participants serve as their own control.

Patients wore the UpRight for a period of two weeks (baseline period; week 1 in which the device was worn but feedback not activated and week 2, the intervention period in which the device was worn with feedback activated) in the patient's home situation (Fig. 1). In the intervention period (week 2) the UpRight was active. Two trained assessors instructed the patients that they should consciously correct their posture in response to the sensory-feedback signal.

Prior the baseline period, patient characteristics were recorded and Hoehn and Yahr scale and the UPDRS were scored. Subsequently the device was applied to the patient in a small pouch on

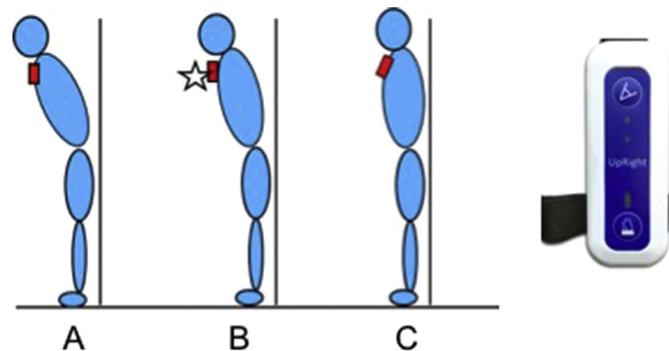


Fig. 1. A: Stooped posture, B: Vibrotactile feedback is given, C: Posture is corrected.

the sternum, cranial to the xiphoid process using an elastic neoprene strap around the thorax. The patients were instructed on how to apply the strap + device to the body in the morning and remove them at night. A calibration for baseline upright posture was performed with the patient standing in a corrected posture. Once attached and calibrated, the UpRight measured and collected data of the patient's postural trunk angles in the sagittal and frontal plane continuously during both weeks. The patient was instructed on usage with an illustrated manual. The assessors kept regular phone contact to confirm proper handling of the device and attachment during the week.

At the end of the baseline period (week 1), the patient's trunk angle data were downloaded and stored for further analysis. Subsequently the correction and feedback function was switched on and the UpRight was reapplied to the patient, indicating the start of the intervention period (week 2). Similar to the first week, the assessors kept regular phone contact with the patients and readjustments (e.g. fit or tightness of the strap) were made if necessary during the second week.

At the end of the intervention period (week 2), patient's trunk angle data were downloaded and stored. Subsequently patient satisfaction, feasibility and user friendliness were assessed using a custom pen-and paper system usability questionnaire, including several Visual Analogue Scales (VAS), one open end question and patients' personal remarks. Patients were unaware of the results from the angle analysis. Safety was investigated by logging adverse events (trips, falls, near-falls and causes) (12).

2.3. Trunk angle sensor and data analysis

When activated in correction mode, the UpRight gives a sensory cue in the form of a vibration feedback signal to the patient, if the trunk angle exceeds a pre-determined threshold value. Specifically, the feedback signal consists of three 160 Hz vibrations of 2 s each, initiated after a delay of 5 s to prevent transient activation of the trigger due to normal daily activities such as sitting down and standing up. The signal recurs after a silent period of 10 s if no correction is made. The threshold angle was specific to each patient and was calibrated and determined by a trained therapist. Settings were dependant on the abilities to actively correct posture and react to the feedback signal.

The trunk angle sensor hardware consisted of a DC-coupled 3-dimensional accelerometer connected with an on-board memory chip, mounted in a user-friendly plastic enclosure. A free software terminal emulator (Tera Term Pro version 2.3) was used to control data collection settings such as sample frequency and sensitivity of the UpRight. Data were collected at 200 Hz. A custom Matlab algorithm was used to visually select the waking hours from a daily activity profile and calculate the mean sagittal plane trunk angle across the 7 measurement days from the raw data collected from the sensor output.

2.4. Outcome measures

Primary outcome measure: Average trunk angle in the sagittal plane in baseline period (week 1) and intervention period (week 2).

Secondary outcome measures: Self-reported Patient satisfaction to determine feasibility and user friendliness of the UpRight. An 11 item questionnaire was used, consisting of: (a) 9-items Visual Analogue Scale (VAS, 10 cm horizontal lines, from worst (left) to best (right): Attachment of device, Weight of device, Wearing comfort, Removing device, User instructions, Discomfort during activities, Charging device, Ease of use, Helps to improve posture; b) item 10, nominal scale on Future use: How many days/week would you wear the device if you would own it? 0 = never, 1 = 1–2 days/

week, 2 = 3–4 days/week; 3 = 5–6 days/week; 4 = daily and (c) item 11, an open-ended question: How much would you pay to purchase this device? Personal remarks were noted during a face-to-face evaluation session.

2.5. Statistical analysis

The difference in number of waking hours and trunk angle between the baseline week and intervention week were analysed using a two-sided paired samples T-test with alpha of 0.05. Linear regression analysis was performed to determine the association between initial trunk angle and the change between baseline and intervention as well as the change between baseline and intervention and self-reported improvement (item 9 of the questionnaire). Descriptives and percentages were used to analyse patient satisfaction, safety, feasibility, and user friendliness.

3. Results

3.1. Participants

15 patients with PD completed the protocol, 13 males, mean age 70.1 (±8.7) years, median H&Y stage 2.5, mean disease duration 8.6 (±4.8) years, mean UPDRS motor score was 25.8 (±10.4) and mean UPDRS Posture score (item 28) 2.1 (±0.43).

3.2. Sagittal trunk angle

No differences were found in the number of waking hours between week 1 (16.2 ± 3.5) and week 2 (16.8 ± 2.8) (data not shown, p > 0.05). An overall statistically significant decrease in trunk angle of –5.6° was observed from the baseline week to the intervention week (p < 0.01; Table 1). 13 out of 15 patients (87%) showed a decrease in trunk angle ranging from –0.8 to –12.8° (mean –6.7°), while 2 patients (13%) had an increase in trunk angle with a range of 1.7 to –1.9° (mean 1.8°).

Linear regression analysis showed a significant association between initial baseline trunk angle (x) and change in trunk angle (y): (y = –0.40x – 0.21, R = 0.54, R² = 0.45, p < 0.05), i.e. patients with larger initial trunk angle (more stooped) showed a larger decrease in trunk angle. In addition, a significant association was found between change in trunk angle (x) and self-reported improvement in posture (y) (y = –0.33x + 5.0, R = 0.77, R² = 0.60, p < 0.01), i.e. patients with a larger decrease in trunk angle also self-reported larger improvements in posture.

3.3. Patient satisfaction by VAS scores: (items 1–8)

Results for the VAS scores with possible range 0 (worst) to 10 (best) are displayed in Table 1. 8 or more patients scored higher than 5 points (halfway the 10 cm line) across all items.

3.4. Self-reported posture improvement by VAS score: (item 9)

The mean VAS score with possible range 0 (worst) to 10 (best) was 6.7 ± 1.9, with 3 patients scoring lower than 5. 2 of these patients did not show a decrease in objectively measured trunk angle (nr. 8 and 3).

3.5. Future use of feedback device by VAS score: (item 10)

Table 1 also shows the scores ‘Future use of feedback device’ (days/week). 13 out of 15 patients (87%) reported that they would use the device for a minimum of 1–2 days per week (category 1–2 or higher), of which 3 patients reported they would use the device

Table 1
Trunk angle data for baseline and intervention week and VAS scores, ordered by initial trunk angle. °: degrees; #>5: number of patients scoring VAS above 5; sd: standard deviation.

Pat. Nr.	baseline trunk angle (°)	intervention trunk angle (°)	mean change (°)	1. Attachment of device	2. Weight of device	3. Wearing comfort	4. Removing device	5. User instructions	6. Discomfort	7. Charging device	8. Ease of use	9. Posture improvement	10. Future use (days/week)	11. Value (€)
8	0,8	2,5	1,7	5,7	5,2	4,9	5,2	6,8	6,4	6,3	6,3	3,5	0	5
3	6,7	8,6	1,9	8,1	4,6	8,5	9,7	3,7	9,8	9,5	9,5	3,1	0	0
7	7,6	5,2	-2,4	6,4	4,8	5,6	1,5	2,0	2,5	3,2	3,2	6,3	1-2	20
14	10,5	0,7	-9,8	6,0	6,6	8,5	4,8	8,9	9,9	6,0	6,0	6,9	7	100
1	11,1	6,8	-4,3	7,5	5,0	7,9	3,0	6,7	6,8	8,5	8,5	7,8	3-4	165
6	11,2	2,7	-8,5	7,2	4,3	9,4	8,0	3,9	9,9	8,9	8,9	5,7	3-4	50
10	11,6	10,8	-0,8	6,9	5,0	2,8	3,7	4,6	8,7	8,3	8,3	5,5	3-4	50
15	12,4	6,6	-5,8	6,8	7,5	8,4	7,6	7,9	7,8	6,6	6,6	6,9	1-2	75
4	13,2	4,4	-8,8	6,8	3,9	9,4	8,9	1,8	9,4	9,3	9,3	9,3	3-4	75
12	14,5	8,9	-5,6	7,0	7,3	9,7	5,2	8,1	1,8	10,0	10,0	8,2	7	80
11	14,6	10,5	-4,1	9,8	6,5	6,0	9,8	1,2	7,1	9,1	9,1	7,5	1-2	50
5	15,2	2,4	-12,8	8,6	4,4	4,7	4,9	9,2	9,1	9,0	9,0	8,2	7	50
9	17,7	8,0	-9,7	7,0	9,4	9,6	9,2	9,3	6,3	6,4	6,4	7,9	1-2	50
13	22,7	18,9	-3,8	7,8	7,0	9,7	8,2	5,5	7,5	6,2	6,2	4,9	5-6	150
2	24,0	15,6	-8,4	8,8	6,2	8,8	4,7	4,8	9,8	8,4	8,4	8,9	3-4	50
mean	12,9	7,5	-5,4	7,4	5,8	7,6	6,3	5,6	7,5	7,7	7,7	6,7	-	65
Sd	5,9	5,0	4,3	8,9	8,5	7,8	7,4	7,2	7,5	8,1	8,1	1,9	-	46
# >5	-	-	-	15	8	12	9	8	13	14	14	12	-	-

daily (7 days). On 'Value of the device in Euro's' 14 out of 15 patients (93%) reported they would be willing to pay on average an amount of 65 euros for the device if it was available in stores.

3.6. Interview and personal remarks

The perceptibility of the signal was good according to 10 patients (66%), 5 patients thought the intensity should be higher (i.e. a stronger vibration). For 8 patients (53%) the signal came too often. All 15 patients used the feedback signal during walking (100%), 7 during sitting (47%) and 1 while standing. 3 patients left the feedback device on constantly, but were inclined to neglect the feedback trigger signal more often, other patients switched the feedback signal on when they felt it was needed and switched it off during other activities. 12 patients could attach the device to the body by themselves (80%) and the other 3 patients needed help (20%). 13 patients (87%) mentioned some or a good effect on their posture, while two patients (13%) did not notice any effect. These patients were also the ones that made the least use of the device and scored the lowest on self-reported posture improvement scores.

5 patients (33%) thought the device was too eye-catching (i.e. visible for other people), 5 patients complained about using the strap, 3 patients (20%) had some technical difficulty using the device such as turning it on and off, or charging. 10 patients (75%) mentioned that they prefer to use the device for short periods during the day, especially during walking.

4. Discussion

The objective of this pilot study was to test the efficacy, practical utility, safety and user-friendliness of a posture feedback and correction device in the home situation of patients with PD suffering from a stooped posture. The data show that self-management of stooping using the UpRight is safe, feasible and effective in an ambulatory setting, and is appreciated by patients for use during walking and gait related activities. While it remains to be determined whether the corrected posture of 5,4° is clinically relevant, the significant association between change in trunk angle and self-reported posture improvement suggests that a certain level of benefit is perceived by the majority of participants. We cannot completely rule out a placebo effect regarding perceived benefit because the intervention was self-evident when the device was used. However, we did include a baseline period of wearing the UpRight without posture correction, so the perceived benefit is likely representative of the effect of the feedback correction.

The significant association between baseline trunk angle (i.e. severity of stooping during daily activities) and the improvement in trunk angle suggests that patients with more severe stooping have greater benefit from the device, but further work is needed to confirm which patients will benefit most from this self-management strategy.

It has been argued that stooped posture may be a protective strategy against backwards postural instability [15]. Correction to a more upright posture could then be argued to be counterproductive and induce instability. On the other hand, Jacobs et al. [16] found that stooped posture is actually a destabilizing posture. They also found increased lateral balance instability in PD, as has been reported earlier by van Wegen et al., [17]. While no adverse events such as falls or near-falls or related patient comments about instability or fatigue were identified in our data, future studies should determine the longer-term effects of this ambulatory postural feedback strategy on postural stability and adaptability during gait-and gait-related activities as well as adverse effects such as falls or fatigue [18,19]. In addition, the UpRight can also

provide feedback on lateral trunk angle accelerations and angles. This is possibly useful to address the lateral instability often seen in PD [17,20], but this needs further study.

The control of posture can be affected in its orientation component (i.e. stooping) and balance component (loss of postural reflexes)/[7,11]. It has been suggested that stooped posture may be due to deficits in proprioceptive processing and integration of posture orientation and balance control [11]. In addition, patients tend not to be aware of bent posture (5) but can correct when asked [14]. We show that the majority of patients are able to correct stooping, so muscle disease or orthopaedic causes of stooping are unlikely. Our results suggest that, at the least, posture correction with use of an external sensory cue is effective in compensating for these proprioceptive deficits, perhaps through directing conscious attention towards bent posture using prefrontal pathways involved in attentional processes as suggested in earlier cueing studies [13,21,22].

Other treatments for stooped posture may include focused manipulative physiotherapy, corsets or spinal braces (orthotics), the use of abdominal binders, and hydrotherapy. However, such approaches may be burdensome, are rarely successful for a sustained period, and have little-to-no evidence base [5]. By contrast posture correction with the UpRight is ambulatory, meaning that no therapist needs to be present for the intervention to work, promoting self-management. However, use of the UpRight probably needs to be embedded in a comprehensive rehabilitation program, directed and coordinated by a trained physical therapist, to be optimally effective.

4.1. Feasibility

Suggestions from patients gave clues about improved use and efficacy of the UpRight. Several patients thought the device was too eye-catching, which would bother them if using the UpRight at work or during social events. The device can be worn underneath clothing, but the operating buttons are then harder to reach. In addition, the perceptibility of the vibration is sometimes poor and this may be optimized by improving skin contact of the device through better fixation of the strap. For several patients, further fine tuning of the correction settings was warranted as they reported the feedback signal as occurring too often, due to voluntary activities such as bending while sitting or standing, working or eating at a table.

Although the present results are promising, the sample size is limited and restricted to moderately affected PD patients. For a definitive answer about a surplus value to postural exercises in usual care exercise therapy, a well-controlled randomized clinical trial is needed to show definitive therapeutic effectiveness of the approach on outcomes of ADL and quality of life, allowing implementation of the UpRight in patients' own home situation during routine rehabilitation therapy.

Conflicts of interest

The authors report no conflict of interest.

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