Forced Exercise - effects of MOTOmed® therapy on typical motor dysfunction in Parkinson's disease

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Abstract

Objective: Additionally to regular medication, alternative drug-free treatments such as exercise or physical therapy, do not cause any side effects and play an important role in Parkinson's treatment. Recent scientific findings suggest very positive effects of movement training at high cadence, the so-called "Forced Exercise" (FE) [26]. The present paper investigates the effects of a home-based passive FE cycling training on general motor function and quality of life in Parkinson's patients.

Study design: 44 Parkinson's patients (68.5 ± 7.8 years) were randomized to control group (n = 23; age: 71.3 ± 4.0 years) and intervention group (n = 21; age: 67.5 ± 7.8 years). The intervention (IG) group completed a 10 week FE cycling program with a motor-assisted movement therapy device (MOTOmed® viva2_Parkinson, RECK). The subjects were encouraged to perform a daily 40 minute MOTOmed® training session, at up to 90 revolutions per minute, in addition to their regular therapy (medication and physical therapy). Motor function and quality of life measures were assessed three times during the study period, a total of 25 test items were recorded (TMTBattery = 15 items, tremor spiral test = 2 items, PDQ-8 = 8 items). Subjects of the control group (CG) continued their standard therapy.

Results: The results of the study show significant improvements in walking ability (walking time: $F = 13.31$; $p = .000$; $p.Eta_2 = .241$; walking steps: $F = 6.44$; $p = .000$; $p.Eta_2 = .133$) and hand coordination (dysdiadochokinesia of the right arm: $F = 3.76$; $p = .03$; $p.Eta_2 = .082$).

Conclusion: Device-supported FE movement training of the lower extremities leads to improvements in walking ability and hand motor function, which suggest FE may be affecting central motor control processes. To proof these findings the authors recommend further studies.

Key words: movement trainer, Parkinson's disease, motor skills, health in Parkinson's disease

Introduction

Parkinson's disease is the second most common neurodegenerative disease after Alzheimer's disease and the most common neurological disease of the basal ganglia [5]. Here, the increasing age of the patients demonstrates the highest risk factor in regards to the development of Parkinson's disease [8, 21, 23]. Between the age of 60 and 70, the morbidity rate is at a maximum [4]. There are only marginal differences concerning the genders with the number of men suffering from Parkinson's being slightly higher [28]. Epidemiologic data prove that there are approx. 200,000 to 250,000 Parkinson's patients in Germany [22]. Due to changes in the aging structure of the population, increasing prevalence data and incidence data are anticipated in the future [6, 21]. Up to now, Parkinson's disease is considered to be incurable [27].

The main symptoms Akinesia, rigor, tremor and postural instability are classified as the typical motor symptoms of Parkinson's and relevant for diagnosis [24, 27]. However, their intensity can differ remarkably and vary both intra- and inter-individually [2]. Medicinal therapy plays a central role in Parkinson's treatment [10]. In addition to the medicinal therapy results of scientific examinations demonstrate that various movement therapies lead to improvements in the symptomatology in Parkinson's patients [9, 12, 20, 25, 29].

New scientific findings also show immediate improvements after assisted, forced cycling at high pedaling rates up to 90 revolutions per minute (FE). The present study is following on the basis of the studies conducted by Ridgel et al. [26] and has observed the effects of a ten-week FE movement training on typical motor dysfunctions in Parkinson's.

The aim of the study was the examination of the effects of an intervention with the movement therapy device MOTOmed® viva2_Parkinson on fine motor skills, coordination, mobility, gait control, tremor as well as the mental state of the Parkinson's patients.

Patients and methods

The subjects were mainly recruited through the support groups of the German Parkinson's association e. V. (dPV) in the area Freiburg - Karlsruhe - Frankfurt - Stuttgart - Ulm - Ravensburg. Overall, 47 participants were randomized into an intervention group (n=24) and a control group (n=23). The study period included three measure points. The T1 test demonstrated an as-is analysis and was conducted at the beginning of the study. The T2 test was done after five weeks in order to examine early effects. After another five weeks, the concluding T3 test was carried out.

	IG (n=21)		CG (n=23)		Total (n=44)	
	MW	SD	MW	SD	MW	SD
Age (years)	67.5	± 7.8	69.4	± 5.8	68.5	± 6.8
Size (cm)	169.3	± 8.2	173.8	± 8.8	171.7	± 8.7
Weight (kg)	81.8	± 15.1	83.5	± 16.0	82.7	± 15.4
Diseased (years)	7.2	± 5.6	11.0	± 7.2	9.2	±6.7
H & Y (stage)	2.69	± 0.75	2.7	± 0.63	2.69	± 0.68

Tab 1: Random examination of control group and intervention group.

The subjects met the following *inclusion criteria*:
1. medically confirmed Parkinson's diagnosis,
2. stage of disease according to Hoehn & Yahr 2-4,
3. subject lives in the area Freiburg - Karlsruhe – Frankfurt - Stuttgart - Ulm - Ravensburg,
4. health condition allows for cycling pedal movements,
5. individual health condition permits independent MOTOmed® operation.

As *exclusion criteria* the following points were determined:
1. health condition not permitting any training sessions,
2. pain interfering with pedal movements of 70 to 90 revolutions per minute

Dropout

Due to health reasons three recruited subjects had to discontinue the study, so the data of a total of 44 subjects was analyzed in the end.

Random examination

At the first measure point (T = 0.03; p = 0.98; df = 42) no significant differences between control group and intervention group could be found concerning the stage of disease according to Hoehn & Yahr. Furthermore, no significant differences between the groups were found (T = 1.92; p = 0.07; df = 42) regarding the duration of the disease since the initial diagnosis. Initial differences in walking performance and dysdiadochokinesia will be excluded from the result part by means of T-tests concerning the performance in T1.

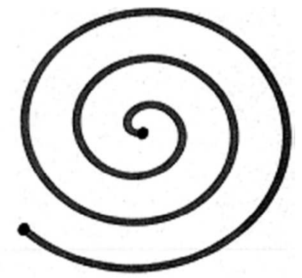

Fig. 1: Tremor spiral

Course of action/ tests

In addition to their usual therapy, the intervention group (n=21) received a ten week MOTOmed® viva2_Parkinson home therapy, five sessions per week for 40 minutes, the control group did not receive additional interventions. The TMT battery and the tremor spiral test consist of Parkinson's specific tasks for the examination of motor dysfunctions. In order to get an insight into the general subjective state of health of each patient, the subjects were additionally provided with the PDQ-8-questionnaire. A total of 25 test items was recorded in the examination (TMT test = 15 items, tremor spiral test = 2 items, PDQ-8 = 8 items).

Timed Motor Test Battery (TMT)

In order to record the motor dysfunctions of the subjects, the TMT battery according to Haaxma et al. was used [11]. The TMT battery consists of a total of 15 test items divided into five test areas (Tab. 2). All test items were carried out at patients' homes except the walking test which took place outdoors for space reasons.
The TMT test presents a good alternative to the motor function part of the Unified Parkinson's Disease Rating Scale (UPDRS-III) since it can be carried out with little time and material effort, it only takes a brief training of the test supervisor and contains no subjective assessment.

Tremor spiral test

The tremor spiral test according to Kraus et al. [19] was carried out in addition to the test item "writing" of the TMT battery in order to prove possible effects of continuous alignment in the tremor symptomatology. In the

Item category	Item (abbrev.)	Test description
Walking[a]	WalkTime	1. Time (sec) needed to walk the final 11 of 15 m
	WalkStrides	2. Number of strides needed to walk the final 11 of 15 m
Writing[a]	WriteTime	3. Time (sec) needed to write a standard sentence[b] on blank paper using the dominant hand
	WriteSpace	4. Horizontal space (cm) needed to perform the writing task
Pegboard[a]		
- Dexterity	Dexterity_r	5. Time (sec) needed to turn eight round wooden pegs upside down using the right hand, from one hole into the next
	Dexterity_l	6. Same, using the left hand
- Double-handed	Peg2Hands	7. Time (sec) needed to interchange two 4-peg rows, 15 cm apart, twice using both hands simultaneously
-Single-handed	Peg1Hand_r	8. Time (sec) needed to displace 16 round wooden pegs using the right hand
	Peg1Hand_l	9. Same, using the left hand
Finger tapping[a]		
- On one key	Tap1Key_r	10. Number of hits on one keyboard key during 5 sec using the index finger of the right hand
	Tap1Key_l	11. Same, using the index finger of the left hand
- On two keys	Tap2Keys_r	12. Sum of hits on two adjacent keyboard keys during 10 sec using the index finger of the right hand, alternating between the two k eys
	Tap2Keys_l	13. Same, using the index finger of the left hand
Dysdiadochokinesia[a, d]	Dysdiadochokin_r	14. Number of table hits, alternating the palm and the back of the hand, during 5 sec using the right arm
	Dysdiadochokin_l	15. Same, using the left arm

Tab. 2: Description of the TMT test (acc. to [11])

[a]= Walking and writing were performed at normal pace. Pegboard, finger tapping, and dysdiadochokinesia had to be performed as fast as possible.

[b]= »Het is mooi weer vandaag« (in English: »The weather is nice today«).

[c]= Patients were instructed to cross their forearms, then simultaneously pick up two wooden pegs opposite to each other at the left and right side of the pegboard, and place them in their opposite holes. This was repeated for each row.

[d]= Rapid alternating forearm movements.

Fig. 2: MOTOmed® viva2_Parkinson

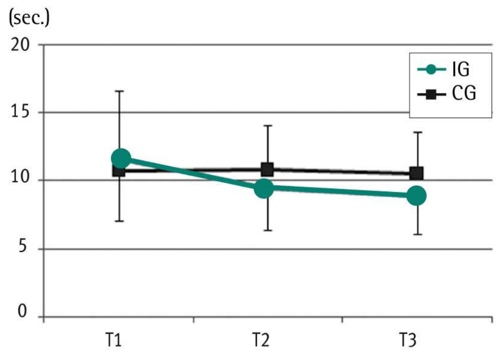

Fig. 3: Walking time

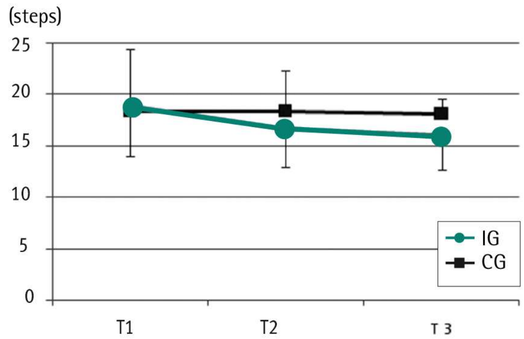

Fig. 4: Walking steps

tremor spiral test the subject runs a pen from the starting point (central point) to the arriving point (see fig.1). In doing so the subject shall retrace the spiral without passovers, if possible. The present study examines the tremor spiral test only with the writing hand, as extreme distortions were to be expected with the other, less-trained hand in some Parkinson's patients, due to strong limitations related to the stage of their disease.
The test supervisor measures the time required for the test exercise (sec.) and counts the number of the exeedances. The tremor spiral scans changes in the alignment.

Parkinson's Disease Questionnaire-8 (PDQ-8)

The PDQ-8 questionnaire is a derived short form of the PDQ-39, developed by Jenkinson et al. It is considered a reliable measurement for the general health condition in Parkinson's disease [17]. Changes in health and the problems caused by illness occurring during the course of the study can be shown with the PDQ-8. The PDQ-8 consists of eight questions. Each question should be answered by marking a box of the five answer options (never, occasionally, sometimes, often, always) (e. g. Did you feel embarrassed in public because of your Parkinson's disease within the last month?).

Intervention

After randomizing both study groups (intervention group and control group) the subjects of the intervention group were provided with a MOTOmed® viva2_Parkinson movement therapy device by the RECK Company for a period of ten weeks. The MOTOmed® can be explained as a modified bicycle ergometer with motor-drive mechanism by means of which even non-ambulant or disabled patients can move their legs in a repetitive manner while sitting in their wheelchair or a chair [18].
The training program given on an individualized chip card consisted of a five-minute warm-up phase where the speed increases successively from 30 to a maximum of 90 revolutions per minute. If a subject was found not to tolerate the maximum speed during the admission the speed was reduced.
Subsequently, the main phase of the training was completed at 90 revolutions per minute for 30 minutes (phase 4). In this training phase the study participants were able to or were supposed to pedal actively on their own, or be moved by the motor (FE). In the end a cool-down phase of five minutes was implemented (phase 5 - 7), in which the speed was gradually reduced.
The data of the training sessions (e. g. duration, speed, active/passive percentage) were saved automatically to an integrated chip card. Each test (T1 - T3) was conducted at the home of the subject by a trained test team of sport scientists.
The control group continued their standard therapy over the whole study period.

Statistics

The examination data were analyzed with the statistic program SPSS version 19. At first, a normality analysis was conducted using a Kolmogorow Smirnow test for all variables and both groups (intervention group and control group). The variables are normally distributed within both groups unless otherwise noted. For the purpose of examination of the effects of the MOTOmed® intervention a variance analysis with measurement repetition was calculated for all elevated parameters (three measurement periods, two groups (IG/CG)).

Results

The results of the study are presented in the dimensions of the TMT structure. Moreover the results of the tremor test and the awareness (PDQ-8) are reported. Relevant to the judgment of the intervention effect in each case is the variance analytic calculated interaction time (T1-T2-T3)*group (IG/CG).

Gait control

Significant interactions between the performance and the group due to the MOTOmed® intervention were shown in regards to the walking time (F = 13.31; p = 0.00; p.Eta² = 0.241) and the walking steps (F = 6.44; p = 0.00; p.Eta² = 0.133). In these items the intervention impacts get particularly visible owing to the significant changes in the first five weeks (T1 - T2) (compare fig. 3 and 4 as well as tab. 3 and 4). In walking time, the IG showed a lower performance of 7.7 % (T = 0.63; p = 0.53; df = 42) at T1, however at T2, the performance was already 12.8 % (1.42; p = 0.16; df = 42) better than in the CG (reference: CG). At T3 a performance difference of 21 % (T = 1.95; p = 0.06; df = 42) in favor of the IG can already be observed. The improvement of 3.24 sec. for the intervention group from T1 to T3 can be considered as practically significant. The critical measurement difference for the walking test (reliability 0.9) is 1.7 sec.
There are similar results in the item walking steps (compare fig. 4 and tab. 4). The IG showed a lower performance of 2.3 % at T1 (T = 0.28; p = 0.78; df = 42), over the study period this group made it at T3 to a performance difference of 11.4 % (T = 2.00; p = 0.05; df = 42) in their favor. The step difference in the intervention group from T1 to T3 is 2.76 steps. This improvement can also be considered as practically significant (critical difference 2.1 steps).

Pronation and supination, right and left hand

There are also significant interactions in the pronation and supination of the right hand (F = 3.76; p = 0.03; p.Eta² = 0.082). In instructed arm rotations, the IG showed a lower performance of 8.6 % (T = 0.91; p = 0.37; df = 42) at T1, made it to a positive difference of 10.5 % (T = 1.28; p = 0.21; df = 42) at T2 and an increase of 3.8 % (T = 0.44; p = 0.66; df = 42) at T3. In the pronation and supination of the left hand the interaction only tends to be significant (F = 2.60; p = 0.084; p.Eta² = 0.058). Here the IG shows 38 % less performance at T1 (T = 0.47; p = 0.64; df = 42). At T2 and T3 a better performance by 6.6 % (T = 0.94; p = 0.35; df = 42) or 12.0 % (T = 1.36; p = 0.18; df = 42), respectively. This difference at T3 stands for approximately two arm revolutions.

Coordination and mobility

No significant interactions in the test items “block turning” with the left and right hand and in the examination of the eye-hand-coordination could be found. The chronological sequences of IG and CG do not vary. There were no significant improvements of the IG compared to the CG in the test item “writing”.

Tremor spiral test

No significant changes in the tremor-spiral-test were noted neither over the whole study period nor in the individual time intervals. No significant interactions could be found out as well concerning the number of failures (F = 0.41; p = 0.63; p.Eta² = 0.010) and time (F = 0.37; p = 0.59; p.Eta² = 0.009).

Walking time		Intervention group (N=21)	Control group (N=23)	Total (N=44)	Diff. to CG
T1	MW	11.57	10.74	11.14	7.7 %
	SD	± 5.05	± 3.67	± 4.35	
T2	MW	9.39	10.77	10.11	-12.8 %
	SD	± 3.08	± 3.32	± 2.25	
T3	MW	8.33	10.55	9.73	-21.0 %
	SD	± 2.75	± 3.09	± 3.03	

Tab. 3: Averages, standard deviations and sample size (N) of the walking time subdivided by IG, CG and total from T1 to T3

Walking steps		Intervention group (N=21)	Control group (N=23)	Total (N=44)	Diff. to CG
T1	MW	18.86	18.43	18.64	2.3 %
	SD	± 5.55	± 4.41	± 4.93	
T2	MW	16.71	18.39	17.59	-9.9 %
	SD	± 3.78	± 3.98	± 3.94	
T3	MW	16.10	18.17	17.18	-11.4 %
	SD	± 3.38	± 3.51	± 3.57	

Tab. 4: Averages, standard deviations and sample size (N) of the walking steps subdivided by IG, CG and total from T1 to T3

Self-awareness (PDQ-8)

The PDQ-8 showed a significant trend in interactions in “dressing” (F = 2.60; p = 0.09; p.Eta² = 0.058) and in “depressions” (F = 2.92; p = 0.06; p.Eta² = 0.065). There were no significantly different group sequences concerning “appearance in public” (F = 0.60; p = 0.55; p.Eta² = 0.014), “personal contacts” (F = 2.23; p = 0.12; p.Eta² = 0.050), “concentration” (F = 0,76; p = 0.46; p.Eta² = 0.018), “communication” (F = 0.42; p = 0.65; p.Eta² = 0.010), “muscle tensions” (F = 2.32; p = 0.11; p.Eta² = 0.052), and “embarrassment” (F = 0.77; p = 0.45; p.Eta² = 0.018).

Discussion

The pilot study of Ridgel et. al showed positive effects of high-frequency assisted cycling training (FE) in Parkinson’s patients for the first time [26].
This study also found significant improvements of gross motor skills and dysdiadochokinesia measure (item dysdiadochokin) by forced exercise. In addition, significant interactions between time and group in favor of the intervention group were observed which suggests a possible success of the intervention. The dysdiadochokinesia measurement is frequently applied in Parkinson’s diagnostics and is an indicator for cerebellar dysfunction (e. g. reduced fine motor skills) as well as for the severity of the disease [13, 15]. An improved dysdiadochokinesia therefore suggests a positive influence on central motor control processes which leads to better movement coordination or hand motor activity, respectively. This effect also has been observed by Ridgel et. al [26] and endorses the assumption of a central effectiveness of forced movement which shall be observed more accurately in future studies. Increased pronation and supination movements (item: dysdiadochokin_r) lead to improvements in daily motor activities (brushing teeth, opening/closing buttons, shaving, etc.). There are some (insignificant) improvements in fine motor skills, seen in small changes in dexterity of the left hand which leads, among other things, to better grasp function. In this context it should be noted that improvements in hand/arm motor activity were discovered although the training program was solely performed with the lower extremities. The shorter time duration (item: walking-time) and the lower number of

steps (item: walking-steps) in the 15m-walking-test suggest improvements in gait control and therefore a reduction of the risk of falls. In summary, the TMT battery proves the intervention leads to rapid effects (T1 - T2) as well as to improvements over the whole study period (T1 – T3) concerning the typical motor dysfunctions in Parkinson's disease. The most significant effects of the MOTOmed® training are noted in the first five weeks (T1 - T2) of the study period.

The results of the tremor spiral test do not show any significant changes. In general, the spiral test proves not to be such an optimal instrument for tremor measurement. Therefore objective, electronic measure instruments, like e. g. the "Kinesia Device" [1, 14], should be used in future studies, if possible.

The PDQ is considered as a soft measure criterion since it exclusively detects the subjective sensation of the person. When answering the questions the answers strongly depend on the daily condition and do not reflect the mental state of the complete test time interval (e. g. between T1 and T2). The PDQ-8 mainly shows slight improvements in the item "dressing". There are rapid effects of the MOTOmed® intervention in the item "depressions". Significant changes where noted between the measure points T1 and T2, however, they did not remain for the further study period. Nevertheless, a positive progress can be detected descriptively which suggests movement therapy has an anti-depressive effect and improves the overall well-being, as seen in other studies [3, 7].

The deviations in the individual daily condition and the strong heterogeneity of the subject groups need to be mentioned as the main limiting factors for the significance of the test results. The symptom deviations often depend on medication (effective period, fluctuations, wearing-off) as well as on the daily condition. These performance fluctuations are partially visible in strong standard deviations in the individual test items. In order to keep these deformations as low as possible the tests with the subjects were always held at the same time (if possible). The subjects had to be trusted to take their medicaments punctually and accurately though. A statement about a long-term sustainability of the intervention method cannot be made. This needs to be proven in further studies. The present study proves effects of the forced, passive movement on the intervention group. However, the possibility cannot be ruled out that other training methods could lead to similar improvements.

Furthermore, the patients chosen for this study were in stage 2 - 4 according to Hoehn & Yahr. This range turned out to be too large as the heterogeneous symptomatology of the patients was related to big differences in their performance. Therefore, a smaller range between stages of the disease should be considered in subject recruitment of future studies, according to the Hoehn & Yahr scale.

Conclusion

The main goal of the study was the examination of the effects of FE training with Parkinson's patients in the stage 2 – 4 according to Hoehn & Yahr. Over the study period of ten weeks 44 subjects with an average age of 68.5 ± 6.8 years participated. 21 subjects were assigned to the intervention group by means of computer based randomization and received MOTOmed® movement therapy in addition to their standard therapy. The intervention group received a daily 40 minute FE training program with the MOTOmed® viva2_Parkinson. The described tests for examination of the intervention were carried out at three measure points.

The present intervention study showed significant positive improvements of the gross motor skills (walking) as well as the hand and fine motor skills (dysdiadochokinesia) in Parkinson's patients deriving from a ten-week FE movement training with a motorized movement therapy device (MOTOmed® viva2_Parkinson). Further items in the fine motor skills also reveal improvements which do not become significant, though. This improvement of the motor activity in the upper extremities due to a training of the lower extremities confirms the hypothesis of an influence of FE on central motor control procedures which Ridgel and colleagues already have expressed in their pilot study [26].

Moreover the FE training is well-accepted by the patients which is not only proven by the gained results but also by the unproblematic, independent realization of the training sessions as well as the large positive feedback of the subjects concerning the MOTOmed® effects and handling. Therefore the integration of a FE movement training program into the therapy concept of Parkinson's patients can be recommended as a reasonable and independently performable therapy addition.

Future studies should try to examine the effect of the central effectiveness more specifically and compare different training points, intensities, extents and frequencies, in order to be able to give differentiated training recommendations to the patients.

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