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Influence of treadmill gait training with additional load on motor function, postural instability and history of falls for individuals with Parkinson's disease: a randomized clinical trial

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ABSTRACT

Background. Evaluate the effects of additional load (5% and 10% of body weight) with treadmill gait training on the motor aspects in Parkinson's disease (PD). Methods. Randomized controlled single-blind trial with 30 individuals with PD. The volunteers were divided into three groups (treadmill with 0%, 5% or 10% load), where Unified Parkinson's Disease Rating Scale was applied. Treadmill gait training was conducted over 4 consecutive weeks, with three weekly sessions of 30 minutes each. Results. There was a significant reduction in all groups in the time factor for motor function ($F = 12.92$; $P = .001$) and postural instability ($F = 11.23$; $P = .002$). No significant difference was observed in group x time interaction ($F < 1.76$; $P > .19$). Conclusion. The treadmill comprises an effective therapy for people with PD, for important motor aspects such as motor function and postural instability. Additional load had no influence on results.

Keywords: Parkinson’s disease; Motor disorders; Gait; Treadmill test; Neurorehabilitation.

INTRODUCTION

Postural instability (PI) is defined as an alteration of the balance that compromises the ability to maintain posture and activities (Kim et al., 2013). In the later stages of Parkinson's disease (PD), there is a decrease of postural reflexes and a consequent increase in PI (Teive and Munhoz, 2014), however, a portion of this population has PI in the early stages of the disease, causing negative impact in quality of life (Hariz and Forsgren, 2011).

Body posture regulation is modulated by the central nervous system, which, through the action of postural reflexes, adjusts posture, balance and body displacement (Massion, 1998). Sensory information also promotes important postural repercussions, particularly in PD, since the individual often needs to use sensory cues as a strategy for maintaining stability (Azulay et al., 1999; Vaugoyeau et al., 2008). Failures in the control mechanisms can cause falls and decreased mobility (Rinalduzzi et al., 2015).

Pickering et al. found 46% incidence of falls in PD over a period of three months (Pickering et al., 2007). Falls resulting from PI have an estimated prevalence of between 38-73% (Dibble et al., 2008). Therefore PI appears as one of the main risk factors for the occurrence of falls, combined with others, such as freezing of gait, cognitive impairment, weakness of the lower limbs, and vestibular and visual disorders (Hunt and Sethi, 2006; Kim et al., 2013; Latt et al., 2009).

Non-dopaminergic lesions seem to affect the regulation of posture and gait (Kim et al., 2013; Macini et al., 2008), shown to be less responsive to levodopa when compared to rigidity and bradykinesia (Steiger et al., 1996). Due to the low responsiveness, treadmill gait training has positive results in terms of gait hypokinesia (Mehrholz et al., 2010). Of the eight clinical trials selected in the meta-analysis of

Mehrholz et al., two assessed the effects of treadmill gait training regarding PI. In these studies, the patients experienced a reduction in PI, the number of falls and fear of falling, as well as improved dynamic balance (Protas et al., 2005), and an increased mobility (Cakit et al., 2007).

It has been suggested that treadmill can be enhanced by the addition of load, which seems to promote improved proprioception with an increased reflex activity of the gastrocnemius and therefore better gait pattern (Filippin and Mattioli, 2010; Toole et al., 2005; Trigueiro et al., 2015). Toole et al. conducted treadmill training with 5% of body mass showing improvement in motor function and balance after six weeks (Toole et al., 2005). Filippin et al. analyzed motor function and quality of life on a treadmill with 10%, showing better results compared to conventional therapy over 18 weeks (Filippin et al., 2010). Trigueiro et al. analyzed which loads (0%, 5% or 10%) would promote better results in motor function and gait kinematics after four weeks. The results revealed that, regardless of the load, all groups showed improvements (Trigueiro et al., 2015).

Considering these data, the use of load during treadmill training seems to be a beneficial strategy for gait rehabilitation; however, only one study (Toole et al., 2005) analyzed variables related to balance and risk of falls. In view of this, the following hypothesis was suggested: Is the addition of load to 5 or 10% during treadmill training able to promote better motor function, thereby reducing the level of PI and consequently, a fewer number of falls when compared to treadmill without load?

MATERIAL AND METHODS

Design and Participants

This is a randomized and blinded clinical trial, structured according to the CONSORT recommendations, at the Laboratory of Interventions and Analysis of Movement of the Federal University of Rio Grande do Norte, Brazil. The participants were selected using the following inclusion criteria: idiopathic PD diagnosed by a neurologist according to the U.K. Parkinson's Disease Brain Bank Criteria (Hughes et al., 1992); aged between 40 and 75 years; being ranked among stages 2 and 3 of the Modified Hoehn & Yahr Scale (H&Y); regular use of anti-Parkinson medication; being able to independently walk a minimum length of eight meters; having no other neurological disorders; absence of auditory and/or uncorrected visual disorders; absence of cognitive disorders that hindered the understanding of simple verbal instructions and not having undergone stereotactic surgery. Exclusion criteria established were: change in dosage and type of antiparkinson medication during training and reports of pain and/or fatigue over two consecutive training sessions.

The sample was allocated at random by means of a simple draw, where participants were randomized into three groups: treadmill training with 0% load (Control – C, N = 10); treadmill training with 5% load (Experimental I – E_I, N = 10) and treadmill training with 10% load (Experimental II – E_{II}, N = 10) (Figure 1). The blindness of allocation was maintained throughout the study period, with the evaluator being blind for the distribution between groups. All participants signed an informed consent form and were recruited from the general community. This study was approved by the Ethics Committee of the Federal University of Rio Grande do Norte, Natal, RN, Brazil (protocol number 063/2011) and registered in the virtual platform of the Brazilian Registry of Clinical Trials – ReBEC (http://www.ensaiosclinicos.gov.br/) under registration RBR – 5qffrt. Patients were recruited from the general community

INSERT FIGURE 1

Instruments and Assessment procedures

Initially, all participants were informed that during the training period they could not carry out any physical activity or physical therapy interventions with emphasis on lower limb training. Pre- and post-training evaluations as well as training sessions occurred during ON time of antiparkinson medications.

Initial evaluation included obtaining demographic and clinical information. Measuring instruments applied were: H&Y, for characterization of PD stage; Unified Parkinson's Disease Rating Scale (UPDRS), for quantification of motor function and to measure relative falls history and PI.

Motor function was evaluated by the motor domain examination, referring to part III of the UPDRS (UPDRSme). The most affected limb was identified by the items

Rigidity and Mobility of the legs, being applied bilaterally. The history of falls was evaluated on the UPDRS part II item 13 (Falls history), and PI on the UPDRS part III item 30 (Pull test or PT). The scores of these items range from 0 (normal) to 4 (greater impairment) (Goetz et al., 2008). As for history of falls, participants were identified as fallers if the score of item 13 was ≥ 1, referring to the previous month (Rascol et al., 2015). The choice for these two items as outcome measures can be justified by the easy application of the test, simple interpretation of the results and for being part of the UPDRS, a gold standard scale in clinical and functional evaluation of PD (Goetz et al., 2008).

After the end of the interventions, the evaluation with the UPDRS was repeated. To minimize risk of bias, all instruments were applied by a single researcher (blind to the allocation of study groups) and following the recommendations of the Movement Disorder Society – MDS.

Training procedures

Gait training was performed on a GaitTrainer® treadmill (GaitTrainer System 2 – Biodex Medical Systems, NY, USA), a jacket was used as a safety measure, without providing body weight support. The three groups performed gait training on a treadmill; however, EI and EII groups performed training with additional 5% load and 10% of body weight, respectively. The additional load was provided by a weight belt with pockets (Seasub®, Brazil), which was positioned at the participant's waist height, due to the proximity to the body mass core in order to avoid postural adjustment problems (Filippin et al., 2010). One kilo lead weights were used to complement the percentage of loads in each of the participants.

For all groups prior to starting the first training session, there was a period of familiarization with the equipment to be used. At each session, the treadmill speed was gradually increased so that the participant was instructed to safely walk at their maximum tolerated speed. The participants were accompanied by a physiotherapist during all training sessions who encouraged them to maintain their postural alignment and to use the frontal support of the treadmill to reduce physical exertion, as well as to monitor any possible complications during the sessions. The participants had their blood pressure and heart rate recorded before and after each session, and heart rate was also monitored by a heart rate monitor during the entire session. The training period was four consecutive weeks, totaling 12 sessions, with three weekly sessions lasting 30 minutes each.

Data analysis

Analysis of Variance (ANOVA) 3 X 2 with repeated measures was used to compare the measures of motor function, PI and history of falls, with group and time regarded as factors of analysis. After finding the normality of data from the Shapiro-Wilks test, the analysis of the relationship between overall motor function and PI was performed using Pearson's correlation coefficient (r), related to post-training values.

Statistical Package for Social Sciences version 21.0 was used for the analysis (SPSS Inc., Chicago, USA), at 1% assigned significance.

Sample characterization measurements are expressed as mean, standard deviation and (absolute and relative) frequency. Outcome measures are expressed as mean and standard deviation, as well as by the percentage of average difference between groups and 99% confidence interval of the difference between the groups. Size effect estimates of each variable are also displayed.

RESULTS

Clinical and demographic data

Thirty individuals with PD met the inclusion criteria and completed the training protocol; 10 women and 20 men with an average age of 62.23 ± 8.96 years (range 41-75), mean age of disease onset 57.53 ± 9.75 years (range 38-72), mean disease duration 4.67 ± 2.32 years (range 2-9). Table 1 shows clinical and demographic data for each training group, indicating there was no difference between them ($P > .29$).

INSERT TABLE 1

Outcome measures

Regarding motor function, a significant reduction of UPDRSme for time factor (F = 12.92; *P* = .001, effect size = .32; power = .93) was observed, however the difference in group x time interaction factor was not statistically significant (F = .17; *P* = .85, effect size = .01; power = .07), indicating that there was an improvement in all groups; however, there was no difference between them. Similar results were also observed for PI. PT score obtained a significant decrease in all groups for time factor (F = 11.23; *P* = .002; effect size = .29; power = .89), although without a significant difference in group x time interaction (F = 1.76; *P* = .19; effect size = .11; power = .34). As for history of falls, no significant changes were observed over time for falls history score (F = 1.00; *P* = .33, effect size = .04; power = .16) nor between groups (F = 1.00; *P* = .38, effect size = .07; power = .21).

The difference between baseline and post-training regarding motor function and PI is presented in percentage (Δ%) in Table 2, due to statistical significance presented by these variables over time. Negative values represent a decrease in the values of the scores (UPDRSme and PT), meaning an improvement in physical performance in the tests.

A total of 63.3% (N = 19) of participants had a score of 0 on item 13 (Falls history) at baseline, indicating that more than half of the sample did not suffer episodes of falls and therefore were not fallers. Regarding the scores obtained in PT before the intervention, a score of 0 ("normal") was obtained by 3.3% (N = 1) of the sample, the score 1 (“suffers retropulsion but recovers without aid”) by 46.7% (N = 14), score 2 (“lack of postural responses; would have fallen if not aided by the examiner”) by 43.3% (N=13), and score 3 (“very unstable, spontaneously loses balance”) by 6.7% (N = 2). Upon completion of the protocol, score 0 was 20.0% (N = 6), score 1 remained the same, score 2 was 30.0% (N = 9) and score 3 was 3.3% (N = 1) of the sample. Table 2 shows absolute and relative frequency scores regarding the history of falls and PT for each of the groups before and after the end of the intervention.

INSERT TABLE 2

Figure 2 shows the correlation between the UPDRSme means and PT post-training, where a moderate positive correlation between these two variables can be observed (Correlation Pearson Coefficient = .560; *P* = .001).

INSERT FIGURE 2

DISCUSSION

The study found that treadmill training promoted significant improvement of motor function and PI in individuals with PD, regardless of the additional load

Values expressed in mean (standard deviation). UPDRSme: motor examination; (N/%): absolute (N) and relative (%) frequency of stag
posttraining. §: effects of time factor; *: $P < 0.01$

percentage used. Toole et al. observed an improvement of motor function through UPDRS motor scores in the three studied groups, so that the addition of the 5% load and partial support of 25% body weight appears to have had no influence on motor performance of patients (Toole et al., 2005). In contrast, in the study by Filippin et al. 10% load was able to provide a significantly greater reduction in UPDRS motor scores between baseline and post-training, compared to conventional physiotherapy (Filippin et al., 2010). Herman et al. found positive results in UPDRS motor scores after four weeks of treadmill training without load, which were maintained over a five-week follow-up period (Herman et al., 2007).

UPDRS was used to analyze motor function and PI in this study since it is considered a gold standard instrument to measure the severity of PD (Goetz et al., 2008), and because it is widely used to investigate short and long term effects of treadmill training (Herman et al., 2009; Mehrholz et al., 2010). The advances observed in the cited studies and the ability to maintain these gains may indicate that the treadmill works by stimulating neuroplasticity (Herman et al., 2009, 2007), and consequently, motor function in PD patients. This hypothesis is confirmed by the findings of this study, which showed that motor improvement was due to treadmill training, since the addition of load did not affect the results. Mehrholz et al., in a meta-analysis showed that patients with PD who underwent treadmill training are more likely to improve gait hypokinesia (Mehrholz et al., 2010), as the treadmill increases the number of practice repetitions and is a specific activity. Thus, advances in overall motor function after training with this equipment is expected.

In addition to motor function, PI experienced beneficial changes in all three groups in the post-training, regardless of the use of load. PI is a clinical symptom that usually develops in later stages over the course of PD (Chong et al., 2011; Visser et al., 2003), becoming a disabling injury approximately a decade after the onset of first symptoms (Wenning et al., 1999). However, in a prospective study with 149 patients, Hely et al. observed that 34% of the sample already had abnormal postural responses after two years of the PD diagnosis, which corresponds to stage 3 of the H&Y scale (Hely et al., 1989; Hoehn and Yahr, 1967). Positive PT scores on UPDRS (scores > 0) (Ebersbach and Gunkel, 2011; Teive and Munhoz, 2014) indicate the transition from stage 2 to 3 on the H&Y scale (Hunt and Sethi, 2006), also indicating bilateral involvement of the disease with the presence of PI, but with functional independence for daily activities (Goetz et al., 2004). In this study, 96.7% of the sample exhibited some degree of PI gauged from PT, even before the intervention. The average duration of PD was over four years and the values of the H&Y scale show that most participants did not fit in the initial phase of the disease (H&Y 1 and 2) (Hely et al., 1989).

Treadmill training has been shown to improve PI at the end of interventions, regardless of the use of load, in spite of PT scores having remained above 1. Previous studies that evaluated the effects of treadmill on PI used different measures of PT, such as Dynamic Posturography (Toole et al., 2005), Berg Balance Scale (Cakit et al., 2007; Toole et al., 2005) and Dynamic Balance Test (Protas et al., 2005). PT or "retropulsion test" was included in the UPDRS in 1987 as item 30, proposing to assess postural stability. According to MDS for test performance, the patient is informed in advance on how the test will be held, then the examiner produces "a sudden posterior displacement, pulling their shoulders back, while the patient is upright with eyes open and feet slightly apart." (Fahn et al., 1987) PT has been questioned as a truly appropriate measure for assessing PI, mainly due to the absence of a consensus on the necessary force/strength, range of the displacement (Ebersbach and Gunkel, 2011; Munhoz and Teive, 2014), and misinterpretation of patient's response to the test (Visser et al., 2003). Choosing PT as a PI measurement in this study is related to the fact that this an easy and fast gold standard test that requires only one examiner, is independent of technological equipment or large floor space for its implementation (Hunt and Sethi, 2006), and having been used as a measure of PI in previous studies (Ebersbach and Gunkel, 2011; Munhoz and Teive, 2014; Visser et al., 2003). It is our understanding that this it is the first study to analyze PT after treadmill training with load.

The hypothesis that treadmill training with load could increase the proprioceptive stimulation of the Golgi tendon organs, facilitating agonist muscle contraction and thus improving the standard motor and postural instability was not confirmed in the present study. Treadmill training alone has been shown to be beneficial in improving postural reflexes (Platz et al., 1998) and in stimulating gait pattern by the continuous stimulation of the treadmill in motion which acts as an external pacemaker, improving rhythmicity and body alignment (Herman et al., 2009). With the improvement of postural reflexes and rhythm of movement promoted by treadmill training, it is suggested that this proprioceptive stimulation alone can justify PI changes observed in this study, since additional loads of 5% or 10% body mass were unable to deliver additional benefits to this variable.

PI has also shown moderate positive correlation with overall motor function in this study. Indeed, the ability to appropriately respond to an external disturbance in body balance not only depends on organization and sensory integration, but also on the muscle tone at rest and on motor adjustment processes in order to promote proper neuromuscular response (Rinalduzzi et al., 2015). The gait training on a treadmill applied for four weeks in this study may therefore have promoted better organization and integration of sensory inputs, and also possible optimization of motor adjustment mechanisms, reflecting on the progress in activities and areas of motor function contained in the UPDRS, among which PI is part of.

Despite PI having been identified among the participants before the start of the intervention, there was no significant differences in the score of item 13 (history of falls) during the intervention. The relationship between PI and falls is somewhat complex to the extent that PI is not the only cause of falls suffered by patients with PD; the phenomenon of freezing and involuntary movements can also contribute to these episodes (Visser et al., 2003).

Patients with PI and deficit in balance tend to adjust their support base to the body's center of mass, and this protection mechanism becomes skilled in adapting to environmental demands, preventing the individual from falling (Bloem et al., 2001; Whitney et al., 1998). Thus, individuals may display PI and not be considered fallers, since they can make use of this postural adjustment capability. This was verified in this study, where the majority (63.3%) reported not having suffered episodes of falls in the last month, even with some degree of PI. This data can justify the absence of positive changes in the history of falls as a result of the interventions in this study, given that the majority of the sample had behavior considered as normal for this outcome.

Study limitations are the small sample and the number and duration of sessions wich may have caused the variable results observed after training. Moreover, the inclusion of other evaluations of balance and PI must be considered, enabling the verification of the most distinct types of postural deficits. It is suggested that future studies be conducted using a prolonged intervention and follow-up to monitor the possible gains retained after the end of treatment.

For future studies, we suggest evaluating patients in ON and OFF states (of taking medication), so it is possible to compare different clinical conditions that represent daily life experienced by patients, and especially to identify whether PT values change under these conditions.

CONCLUSIONS

In conclusion, the present study has shown that treadmill gait training is a beneficial therapy for people in a moderate stage PD, as it promotes improved overall motor function and PI in these patients. Sensory manipulation with the use of additional loads (5% and 10%) had no influence on the results. No group was superior to others, showing that gait training on a treadmill represents an effective therapy for rehabilitation of PD patients, and improves important aspects such as motor function and postural stability of these individuals.

STATEMENT OF FINANCIAL DISCLOSURE

The authors declare that they have no funding sources or identified conflicts of interest to declare.

CONFLICT OF INTEREST

None.

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Table 1. Patient characteristics divided according to conditions (0%, 5% and 10% load).

Variables	Treadmill + 0% load (n=10)	Treadmill + 5% load (n=10)	Treadmill + 10% load (n=10)	*P*
Age, yrs	62.60 (6.79)	60.40 (11.71)	63.70 (8.33)	0.72
Male (M)/Female (F)	5M/5F	6M/4F	9M/1F	
HY	2.55 (0.37)	2.55 (0.44)	2.60 (0.39)	0.95
HY n (%)				
Stage 2	2 (20%)	3 (30%)	2 (20%)	
Stage 3	8 (80%)	7 (70%)	8 (80%)	
Age of onset, yrs	57.70 (8.08)	55.70 (12.13)	59.20 (9.32)	0.74
Disease duration, yrs	4.90 (2.47)	4.60 (2.72)	4.50 (1.96)	0.93
Weight, kg	61.40 (10.21)	63.90 (12.89)	69.80 (12.48)	0.29
More affected lower limb, Left (L)/Rigth (R)	4L/6R	2L/8R	1L/9R	

Values expressed in mean (standard deviation). Yrs: years;cm:centimetres; Kg: quilograms; *P*: p-value. (N/%): absolute (N) and relative (%) frequency of stages.

Table 2. Comparison of motor examination (UPDRSme), Falls history and Pull test scores between baseline and posttraining.

Variables	Treadmill + 0% load (n=10)			Treadmill + 5% load (n=10)			Treadmill + 10% load (n=10)			CI 99%
	Baseline	Posttraining	Δ%	Baseline	Posttraining	Δ%	Baseline	Posttraining	Δ%	Lower (Upper)
UPDRSme$^{\delta}$	17.50 (12.49)*	12.30 (8.86)*	-29.7%	26.00 (14,10)*	19.30 (14.27)*	-25.8%	19.30 (15.37)*	14.70 (12.81)*	-23.8%	13.52 (22.85)
Falls history score	.60 (0.70)	.60 (0.70)		.40 (0.52)	.30 (0.48)		.20 (0.42)	.20 (0.42)		.18 (0.59)
Falls history score n (%)										
0	5 (50%)	5(50%)		6(60%)	7 (70%)		8 (80%)	8 (80%)		
1	4 (40%)	4(40%)		4(40%)	3 (30%)		2 (20%)	2 (20%)		
2	1 (10%)	1(10%)								
Pull test score$^{\delta}$	1.60 (0.52)*	1.20 (0.63)*	-25.0%	1.70 (0.68)*	1.10 (0.88)*	-35.3%	1.30 (0.82)*	1.20 (0.92)*	-7.7%	1.09 (1.61)
Pull test score n (%)										
0		1 (10%)			3 (30%)		1 (10%)	2(20%)		
1	4 (40%)	6 (60%)		4 (40%)	3 (30%)		6 (60%)	5 (50%)		
2	6 (60%)	3 (30%)		5 (50%)	4 (40%)		2 (20%)	2 (20%)		
3				1 (10%)			1 (10%)	1 (10%)		

Values expressed in mean (standard deviation). UPDRSme: motor examination; (N/%): absolute (N) and relative (%) frequency of stages. CI: Confidence Interval 99%; Δ%: change between baseline posttraining. §: effects of time factor; *: $P < 0,01$.

CONSORT Flow Diagram

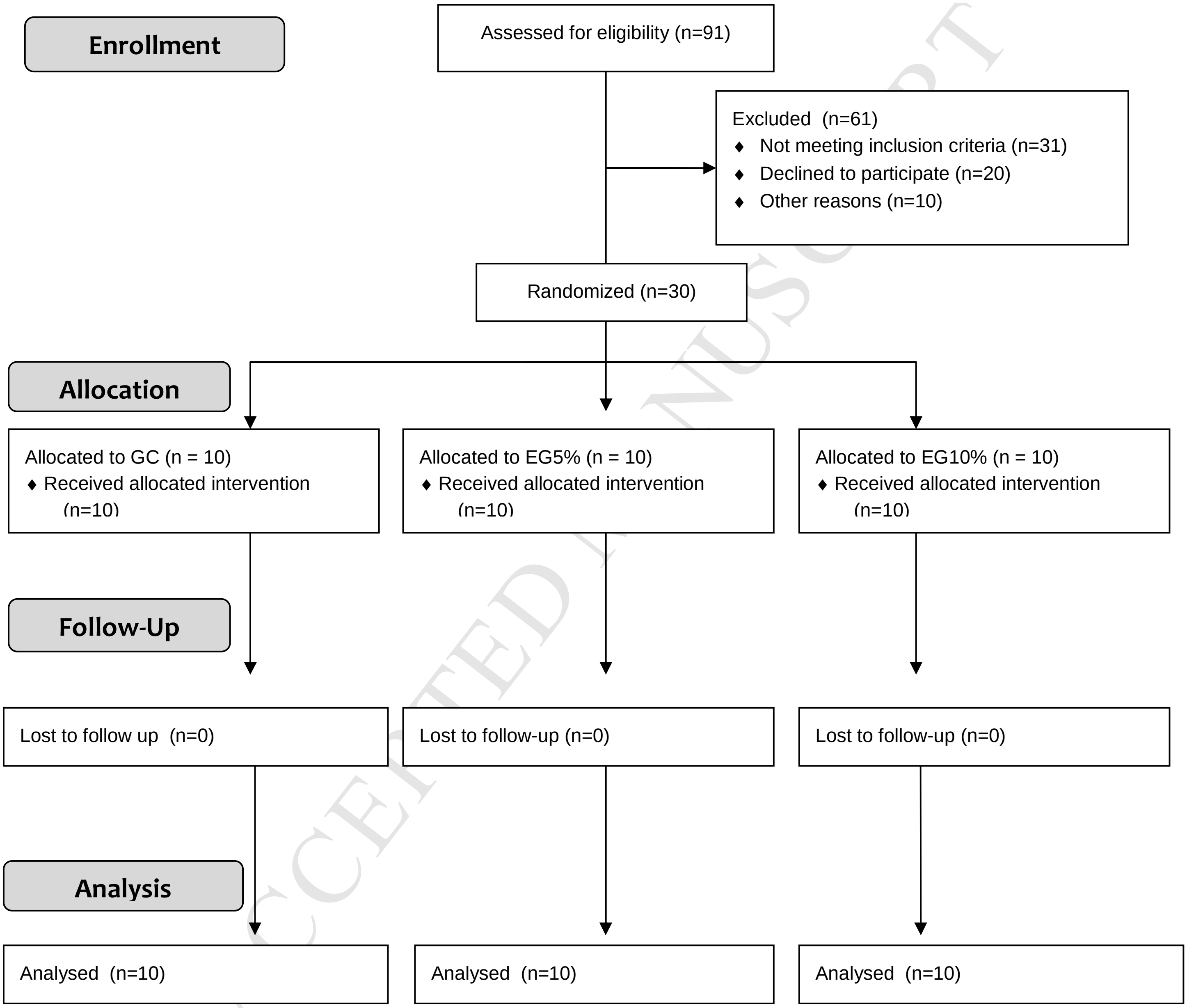

Figure 1. Flow diagram of participants

Figure 2. Correlation between the values of motor examination (UPDRSme) and Pull test score posttraining (r = 0,56)