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ORIGINAL RESEARCH ARTICLE

Scaling new heights: a pilot study of the impact of climbing on balance, agility, and dexterity in individuals with Parkinson's disease

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ABSTRACT

Introduction: Exercise is known to be beneficial for individuals with Parkinson's disease (PD). Rock climbing contains exercise characteristics highlighted in published clinical guidelines for PD (e.g., aerobic, resistance, balance training, cued-movements, community-based) and also has unique somatosensory and visuospatial experiences that may facilitate motor learning. The purpose of this study was to investigate the effects of a climbing program on the physical function of individuals with PD.
Methods: This quasi-experimental observational pilot study used pre-to-post-test comparisons to assess participants with mild to moderate PD (Hoehn and Yahr 1-3) who walked independently. The intervention was 12 weeks of community-based, twice weekly top-rope climbing sessions under one-on-one supervision and tailored to skill level. Wall angles, hand/foot holds, and routes varied from climb to climb and became progressively more difficult as skills increased. The primary outcome measure was the Community Balance & Mobility Scale (CBMS); secondary measures were the Agility T-Test (ATT), 9-Hole Peg Test (9HPT), upper extremity reaction time using BlazePods (UE-React), and grip strength (GS).
Results: 28 participants completed the study: 8 women/20 men; mean age = 66.1 (sd = 7.4) years; average disease duration = 4.0 (sd = 3.6) years. *Paired t-tests* comparing pre- and post-test scores and effect sizes (ES) with 95% confidence intervals (CI) were calculated for statistically significant results using *Hedge's g*. Findings were: CBMS (p < 0.001; ES = 0.573, 95% CI = 0.178-0.960), ATT (p < 0.001; ES = 0.462, 95% CI = 0.078-0.838), 9HPT (p < 0.001; ES = 0.480, 95% CI = 0.094-0.858), UE-React (p <0.001; ES = 0.329, 95% CI = −0.045-0.696); GS changes were non-significant.
Conclusions: Rock climbing demonstrated medium-size effects on mobility/balance and small-size effects on agility and dexterity that could impact functioning in everyday activities.

Keywords: motor learning, physical activity, Parkinson's disease, rehabilitation

What is already known about this topic?

- *Physical activity is known to be beneficial for individuals with PD, and certain components have been highlighted in clinical practice guidelines as key characteristics (e.g., aerobic, strength, and balance training, cued responses, and community-based). Rock climbing encompasses all of these traits.*

What does this study add?

- *Rock climbing contains multiple PD-recommended exercise components in one activity and offers unique motor learning experiences for individuals with PD. Vertical climbing training could lead to improved horizontal over-ground performance.*

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Introduction

Parkinson's Disease (PD) is a major public health crisis in the making. It is the second most common neurological condition after Alzheimer's disease, affecting nearly 1 million people in the US (1) and causing a significant public health burden (2). While there are a few treatment options that may mitigate symptoms, there is currently no cure for this health condition.

Exercise is commonly prescribed for individuals with PD as both an intervention for and prevention of further disability (3,4). Ernst et al. support the beneficial effects of physical exercise, including gait/balance/functional exercise and multi-domain exercise, on motor signs in PD (4) Osborne et al. offer clinical practice guidelines that include multiple types of activity interventions (e.g., aerobic, resistance, balance, externally cued, community-based) (5). Performance-based interventions emphasizing aerobic intensity and resistance training in community settings have gained traction among patients and health professionals (5), including dancing (6), and boxing (7). Despite their increasing popularity, the evidence base for these programs is still developing and far from conclusive (8). More recently, rock climbing programs have been identified as providing potential therapeutic benefits for people with PD (9-11) and other health conditions (12,13). Rock climbing uniquely encompasses many of the recommended characteristics of activity interventions (4,5). Langer and colleagues (9-11) suggest that climbing might positively impact motor symptoms, posture, and gait speed in individuals with PD.

The purpose of this pilot study was to identify the primary physical effects associated with participating in rock climbing on functional performance for tasks of community mobility and upper extremity (UE) functioning. The specific aims of this study were to characterize the effects of rock climbing on a primary outcome of mobility and locomotion, as well as secondary outcomes of agility, dexterity, UE reaction time, and grip strength (GS). Based on anecdotal evidence and the limited research available, we hypothesized improvement in all outcome measures.

Methods

Study Design

This pilot study used a quasi-experimental observational design to follow a cohort of individuals with PD who had limited to no exposure to rock climbing. Participants completed physical performance tests twice, prior to the first climbing session and then again after completing 24 sessions for before and after comparisons.

Target Population

Consenting adults with mild-to-moderate PD (Hoehn and Yahr 1-3) who met the inclusion criteria were eligible to participate.

Recruitment

Participants were recruited from the greater Washington DC metro area by word of mouth, healthcare provider referral, support groups, social media, and posted fliers. Interested individuals were directed to a recruitment website that listed the specific inclusion and exclusion criteria to participate, allowing prospective participants to self-determine their eligibility before contacting the research team for screening. Prospective participants then contacted one member of the research team (MC) who confirmed eligibility, reviewing each of the inclusion and exclusion criteria. Data collection occurred in an exercise room at the climbing gym and spanned August 2023 to August 2024.

Inclusion criteria were: $\geq$18 years old; diagnosis of PD by a health professional; Hoehn and Yahr score 1-3; able to speak and read in English; and able to ambulate at least 10 meters with no assistive device or human assistance. Exclusion criteria were: Diagnosis of neurological disease other than PD; uncontrolled cardiovascular, pulmonary, neurological, or metabolic disease which might impact the ability to exercise or for which exercise is contraindicated; cognitive or psychiatric impairment precluding informed consent or ability to follow instructions; and pregnancy. Participants engaging in routine physical activities were included in the study, but participants did not begin any new structured exercise over the course of the study.

Ethics Approval

The pilot study proposal was approved by the Marymount University (Arlington VA) Institutional Review Board (IRB Protocol #831) and registered on Clinical Trials (NCT05919771). Consent was obtained by a single member of the research team (MC).

Intervention Description and Protocol

For the purposes of this pilot study, rock climbing was described as a vertical ascent of a surface specifically designed to elicit the skills that might be required to scale a naturally occurring rock formation. The rock climbing experiences offered by UpENDing Parkinson's (UEP), a non-profit organization that has provided free training in rock climbing for individuals with PD since 2012 (https://www.upendingparkinsons.org), served as the study intervention. Sessions were integrated into an existing group of climbers with PD and conducted under one-on-one supervision using a harness and rope to belay the climber (consistent with "top-rope" or "sport" climbing). Sessions were supervised by UEP volunteers with extensive climbing experience and were tailored to the skill level of the participant. The angles of the walls, the holds on which climbers grab or step, and the routes varied from climb to climb, and climbers progressed to more difficult courses as their skill levels increased. Participants had the opportunity to climb two times per week free of charge. Study participants could also climb outside of group climbing sessions if they received safety clearance from the UEP staff. Participants were encouraged to climb at least two times a week but no more than three times in a seven-day period, and attendance was monitored by UEP staff upon entering the climbing facility. Post-test data were collected after 24 climbing sessions, which generally took participants ~12 weeks to complete.

Outcome Measure Selection

Our study team relied on a research advisory group that included a climber with PD and the spouse of a climber to identify the array of concepts relevant to physical mobility and well-being. With this group's input, we selected candidate instruments for further review. Following the initial culling of potential tests and measures, the research team gathered a small group of experienced climbers with PD for a trial administration of measures to identify floor and ceiling effects of the proposed instruments. Additionally, to finalize the battery of tests and measures used in this study, the same experienced climbers participated in a focus group to provide feedback on what outcomes were important and meaningful to them as individuals living with PD.

Primary Outcome Measure

The primary outcome measure for this observational study was a modified version of the Community Balance and Mobility Scale (14) (CBMS) consisting of eight separate upright mobility tasks, four of which are performed with both left and right lower extremity (LE). The eight tasks were selected from the original 13 based on feedback regarding redundancy across tests and subject fatigue provided by our test group of experienced climbers with PD. The CBMS was scored from 0-60 with higher scores indicating better performance.

Secondary Outcome Measures

Four other measures were used, including the Agility T-Test (ATT) (15), in which a participant is timed as they move quickly toward cone targets that they must tap with a hand, moving forward, laterally to the left, laterally to the right, back to the left, and then backward to their starting point. Faster scores denote better agility.

The Nine-Hole Peg Test (16) was used to assess UE dexterity. This test measures the time it takes to remove nine pegs (about the size of a golf tee) from a tray, place each peg in a hole, and then remove the pegs and place them back in the tray. Participants were seated at a table and chose which hand to test (stabilizing the peg board with the other hand) and repeated with the same hand on post-testing. Faster times indicated better dexterity.

Reaction time (quantifying the combined cognitive and physical response) was captured using the BlazePod®[a] system (17). A standard semicircle of four pods (pod cases were affixed to plywood base) emitted red light stimuli in a random sequence to trigger the participant's firm tap of the light source. Participants were seated with the pods on the table in front of them and could use either or both hands to respond to lit pods. Total reaction time was the system's recorded time response to 30 random flashing stimuli, with lower scores denoting better reaction time.

Grip strength (GS) (16) is a measure of force production that was assessed using a standard hand-held dynamometer (Jamar[b]), yielding the force output in pounds, with higher force representing greater strength. Participants sat in a chair with their arms at their side and elbow in ninety degrees of flexion. Participants chose which hand to test and repeated with the same hand on post-testing.

Data Collection Procedures

Data collection procedures were taught to volunteer climbers and physical therapy student research assistants by the lead researchers (two physical therapists and one climbing instructor) and practiced several times before the first participant was tested. Participant testing sessions occurred within two weeks of beginning/finishing the 12-week intervention. One author (AG) had minimal involvement in data collection and did not engage in the pre- or post-test of the same individual, in any case, to remain blinded to the results, and two authors (JR and AG) did not attend any of the climbing sessions. Data analysis was performed using a deidentified data set.

Data Analysis, Power, and Sample Size

Descriptive statistics were evaluated by calculating the mean, standard deviation, and range for ratio data and evaluating percentages for nominal data. Outcome data were assessed for normal distribution using the *Shapiro-Wilk Test*. Then, each outcome measure was analyzed using *paired t-tests* to compare pre- and post-test values. Because there are no studies of rock climbing using community mobility as the primary outcome, the research team proceeded very conservatively with power and sample size estimations based on a desired effect size (ES) of 0.5. A Cohen's *d* of 0.2 is generally considered to be "small," 0.5 to be "medium," and 0.8 to be "large." (18) In the context of a rehabilitation intervention study, a moderate ES is generally considered to be clinically meaningful. We computed our sample size based on our primary variable, CBMS, using a one-tailed paired t-test with a significance level of 0.05 and 80% power. Based on our calculations, our *a priori* required sample size was 27 individuals with PD.

Because ES may be inflated in small samples and the preliminary nature of a pilot requires statistical restraint, we chose to estimate ES for within-subject differences using IBM SPSS Statistics (Version 29.0.2.0)[c] in the most conservative (i.e., unbiased) way by calculating *Hedge's g* [with 95% confidence intervals (CIs)], which uses the square root of the average variance of measures in the denominator, plus a correction factor.

Results

A total of 32 participants consented to the study, of whom 28 completed 12 weeks of training and both pre- and post-testing sessions. The drop-out rate was 12.5%, far less than typically expected for an exercise study (19, 20). Of the four subjects who did not complete the study, two reported a lack of interest in rock climbing, one became too busy to climb regularly, and one experienced a shoulder injury unrelated to the study. Comparisons of participants who completed the study and those who did not, showed no appreciable differences with respect to age (*independent t-test*: $t = 0.161$, $p = 0.881$), time since PD diagnosis (*independent t-test*: $t = -1.468$, $p = 0.230$), or Hoehn and Yahr score (*chi-square test:* $\chi^2 = 2.245$; $p = 0.326$), but non-completers were different in sex distribution (*chi-square test:* $\chi^2 = 8.837$; $p = 0.014$), in that all four were female. There were no adverse events during the course of the study.

Table 1 presents the demographics of the participants who completed the study. In general, participants were mostly male older adults with PD for less than 5 years and less severely impacted by the clinical signs and symptoms of PD, as evidenced by Hoehn and Yahr scores. All participants self-reported their health as either good or excellent, and most exercised routinely prior to entering the study.

TABLE 1 - Participant demographics

Participant Characteristic	**Study Participants (n = 28)**
Mean Age (years [sd], range)	66.1 [7.4] Range 45-78
Sex	28.6% Female (8) 71.4% Male (20)
Disease Duration (years [sd], range)	4.0 [3.6] Range 1-14
Hoehn & Yahr (H&Y) Score	64.3% H&Y 1 (18) 25.0% H&Y 2 (7) 10.7& H&Y (3)
Race/Ethnicity	85.7% White (26) 7.1% Hispanic or Latino (2) 7.1% Declined to Answer (2)
Education	64.3% Graduate Degree (18) 3.6% Some Grad School (1) 25.0% Bachelor's Degree (7) 3.6% Tech School Degree (1) 3.6% Some College (1)
Self-Health Rating	21.4 % Excellent (6) 78.6% Good (22)
Participate in Regular Exercise	92.9% Yes (26) 7.1% No (2)
History of Falls (Y/N)	25% Yes (7) 75% No (21)

Paired t-tests for the outcome measures demonstrated statistically significant improvement in performance on four of the five outcome measures (Table 2). There was no statistically significant change in GS, one of the secondary outcome measures. We calculated an ES for each of the four statistically significant comparisons to gauge the magnitude of the change. As displayed in Table 2 as point estimates and 95% CIs, we found medium ES for our primary outcome measure, CBMS. We found small ES for three of our four secondary outcome measures [ATT, 9-Hole Peg Test (9HPT), and Reaction Time as measured by BlazePods®]; however, the Reaction Time CI includes zero, impacting our confidence in the estimate of ES on this outcome.

Discussion

This observational pilot study of a 12-week climbing intervention for individuals with mild to moderate PD demonstrated participant improvement, with a medium effect on mobility and balance (CBMS), the primary outcome, and a small effect on agility (ATT) and dexterity (9HPT). There was negligible effect on UE reaction time and GS.

The growth of climbing as a therapeutic adjunct has followed the expansion in popularity of climbing in the fitness community and has a history of use in orthopedic conditions, depression, and multiple sclerosis (13). To our knowledge, there is one published study on top-rope climbing for people with PD, a randomized controlled trial that is the subject of three separate publications (9-11) Langer and colleagues demonstrated that a 12-week, once per week 90-minute top-rope climbing intervention for participants with mild to moderate PD resulted in improvements in motor symptoms (9), posture (10), and gait speed (11). Our positive results are consistent with the findings of that study.

Exercise is known to be therapeutic in the management of PD motor signs and symptoms (21,22), although a recent Cochrane review finds fault in the rigor of evidence for exercise in existing research (4). Physical therapy clinical practice guidelines (5,23) strongly support exercise that has aerobic and resistance training components, balance demands, external cueing, and takes place in a community-based format – all characteristics that are found in climbing. These traits are not unique to climbing, but climbing provides all of these in a single session.

Climbing also encompasses many routinely supported principles of exercise and activity interventions. The principle of progressive overload of biomechanical and bioenergetic demands is a well-supported framework in musculoskeletal and cardiopulmonary systems training, and an appropriate level of challenge is pivotal to driving neuroplastic changes. The difficulty level of routes and the amount of support provided by the belayer are dynamic variables contributing to overload and challenges that are modified over time. Climbing offers variability within and between climbs, and

TABLE 2 - Mean differences, standard deviations, significance, and ESs with 95% CIs for outcome measures

Outcome Measure	**Mean Difference**	**Standard Deviation**	***t statistic***	***p-value***	**ES** (*Cohen's d*) **(95% CI)**
CBMS	6.250	6.942	4.764	<0.001	0.573 (0.178-0.960)
ATT	2.419	3.417	3.746	<0.001	0.462 (0.078-0.838)
9HPT	2.148	3.125	3.637	<0.001	0.480 (0.094-0.858)
Reaction Time	0.740	0.998	3.922	<0.001	0.329 (−0.045-0.696)
GS	1.661	14.337	0.613	0.273	N/A*

CI = Confidence Interval; CBMS = Community Balance and Mobility Scale.
Mean Difference = Difference between pre- and post-test scores on each outcome measure.
*Effect size calculation not applicable (N/A) due to lack of statistically significant findings.

practice variability has long been considered critical to creating broad and adaptable movement strategies.

Additionally, there are novel components to climbing that are not readily found in other therapeutic or activity interventions that foster motor adaptation. Table 3 identifies some of the unique characteristics of therapeutic rock climbing as related to our understanding of current motor control and motor learning theory. Of particular note are the advantages of rock climbing with respect to our emerging understanding of the optimization of motor learning in the context of social, cognitive, and affective domains. The Optimizing Performance Through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory (24) emphasizes autonomy and enhanced expectations of the learner with an externally focused goal. Rock climbers are encouraged and empowered to solve the sequence of motor problems at hand: they “take on” the wall with the expectation of success. In summary, rock climbing as a physical activity mimics many of the characteristics of structured exercise programs, but it also offers the critical attributes of enhanced motor learning offered by the OPTIMAL theory.

Our findings suggest that participants adapted in response to the challenges of climbing. Participants did not just get better at climbing (task-specific improvements as evidenced in their progression of climbing skill level over the course of the study) but demonstrated improvement in functional movements relevant to upright mobility and activities of daily living. Motor learning is the result of experience-dependent neuroplasticity (25), and the capacity to benefit from exercise-induced neuroplasticity in individuals with PD has been documented (3,26). Individuals with PD are capable of motor learning, although the speed, scope, and generalizability may be less than that of healthy individuals (27). Our findings strongly suggest that rock climbing can support enhanced motor learning and promote movement capabilities beyond task-specific gains.

Climbing, a form of “vertical quadruped locomotion” (28) training, appears to have translated to horizontal bipedal mobility gains in this pilot data. Although we cannot speculate beyond the limits of this study, future research should explore the neuroanatomical underpinnings of motor learning in PD. There is a tendency in the rehabilitation literature

TABLE 3 - Unique motor control and motor learning characteristics of therapeutic rock climbing

Unique to Rock Climbing	Specific Characteristics or Demands	Motor Control and Motor Learning within the Context of Founding Theories
Vertical Orientation	• The vertical orientation of the movement task drives substantially different demands on posture and movement (vs. traditional movement in the horizontal plane as in over-ground activities) • Orientation to the wall counters flexion posture tendency and anterior (sagittal plane) instability	• Changes movement landscape: Removes climber from habitual, entrenched movement strategies (i.e., deep “attractor wells” in *Dynamic Systems Motor Control Theory)*, providing an opportunity for discovery of untapped movement potential (30)
	• Unique somatosensory experiences (e.g., the stable surface is anterior to the climber; position of body and extremities is constantly changing; different holds and wall contours force climber to adapt; feel of harness, shoes, ropes) • Unique visuospatial experiences (e.g., functioning at different elevations, locating and targeting movement to appropriate holds) used in perception-action coupling	• Ongoing assessment of relevant environmental and task cues within the perceptual-motor workspace in the context of goal-directed behavior (*Ecological Motor Learning Theory*)[31]
Full-body engagement	• Bilateral inter- and intra-limb coordination demands in multiplanar directions and varying amplitudes with repeated midline crossing • Open and closed chain functioning of all extremities requires varying mobility and stability skills	• Application of practice variability and movement complexity forces expansion of the behavioral repertoire (32, 33)
Cognitive demand	• Concurrent cognitive demands of determining the route and optimal moves: Constantly making decisions about how to orient/arrange one’s body and extremities relative to the wall/holds for best success	• Dual-task (motor and cognitive) training is effective in improving single and dual-task performance in PD (34, 35)
Salutary stressors	• Poses therapeutic level of stress/anxiety (associated with novelty, heights, equipment, etc.) • Consistently increasing challenges by progressive overloading of biomechanical and bioenergetic demands	• Stressors “prime” the neuromotor system for adaptability (36, 37)
Task-oriented goal in a unique setting	• Integrates expectation of success, and autonomous control over movement and goal attainment	• Facilitates motivation and confidence of learner (*OPTIMAL Motor Learning Theory*) (24)

to delineate types of motor learning to specific brain regions: The pre-frontal cortex for strategy-based learning; basal ganglia for reward-based learning; the motor cortex and spinal cord for repetition-based learning; and cerebellum for error-based learning (25). This makes it tempting to conclude that those with PD (a primarily basal ganglia pathology) are unable to benefit from reward-based learning (basal ganglia mediated). It may be more accurate to acknowledge that motor learning is not the product of mutually exclusive functioning of different brain areas but rather the result of shared responsibility of multiple dynamic and adaptive systems and substrates (29).

Future research may also determine the best methodology for documenting outcomes related to climbing, as some of our secondary outcome measures (i.e., reaction time using BlazePods® and GS using hand-held dynamometer) did not show the results we anticipated.

Limitations

The generalizability of this pilot study is limited by the lack of a control group and a small sample despite the adequate power to detect change. Assessors were not blinded to the purpose of the study. Our findings are limited to novel climbers immediately following a 12-week climbing intervention. Furthermore, as in almost all exercise and physical activity studies, participants are a self-selected group whose interests match the study intervention. Our participants were generally healthy, routine exercisers with less severe PD for less than 5 years on average. Moreover, they were very well educated and white, social determinants of health that are known to positively influence health outcomes. Interpretation of the data is hampered by a lack of comparative studies that would allow a more complete assessment of the context and import of our findings.

Conclusion

Rock climbing appears to have modest positive effects on physical performance that may benefit individuals with PD in their everyday lives. The findings of this study may be a basis for future research, which may establish rock climbing as a viable adjunct to traditional medical and rehabilitation therapies to reduce the impact of this health condition and enhance physical well-being in this population.

Ethical Approval

This study was approved by Marymount University (Arlington VA USA) IRB as Protocol 831 on June 19, 2023. All participants gave written consent and signed Informed Consent documents, which are in the possession of the principal researcher.

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Disclosures

Conflict of interest: The second author, Molly Cupka, is the President and Founder of UpENDing Parkinson's, which is the organization that provided climbing instruction and oversight for the participants of this study. The other authors, Julie Ries and Andrew Guccione, have no conflicts to report.

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Author contributor roles: JR: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Supervision, Visualization, Writing (original draft), Writing (review & editing); MC: Conceptualization, Data Curation, Investigation, Methodology, Project Administration, Resources, Supervision, Visualization, Writing (review & editing); AG: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Visualization, Writing (original draft), Writing (review & editing).

Data availability statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available.

Clinical trial protocol number: This study was registered with clinicaltrials.gov with registration number NCT05919771 and title "Effects of Rock Climbing on Parkinson's Disease." (https://clinicaltrials.gov/study/NCT05919771)

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