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*Original Research*

# Borg scale is valid for ratings of perceived exertion for individuals with Parkinson's disease

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ABSTRACT

***International Journal of Exercise Science 10(1): 76-86, 2017.*** Parkinson's disease is a neurodegenerative disease that has traditionally been treated with anti-parkinsonian medication. There is increasing evidence that exercise is beneficial to those with PD, therefore, it is necessary to validate a measure of exertion that can be implemented across exercise settings that may not have the capability to actively monitor heart rate. The aim of this project was to determine the validity of the Borg RPE scale in individuals with PD undergoing a maximal progressive cycling exercise test. Thirty-eight males and females (58.5 ± 8.1 yrs) with a clinical diagnosis of idiopathic PD, Hoehn and Yahr stage II-III, completed a maximal exercise test. Heart rate was monitored continuously, with RPE being recorded during the last minute of each stage of the test. Correlation analysis was used to evaluate the relationship between RPE and continuous heart rate monitoring. A significant, positive correlation was present between RPE and heart rate and RPE and workload, $r = 0.61$ and $r = 0.77$ respectively. A separate mixed effects model regression analyses indicated that RPE was a significant predictor of heart rate ($p < 0.001$) and workload ($p < 0.001$). The results of a mixed effect models that RPE scores indicated that RPE values at commonly prescribed workout intensities were not associated with age, gender, or disease severity ($p>0.05$). Significant, positive correlation between RPE and HR indicates that the Borg category ratio scale may be used in individuals with Parkinson's disease in which formal exercise testing may not be available.

KEY WORDS: Parkinson's disease, perceived exertion, exercise, Borg scale, heart rate

## INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative disorder characterized by a loss of dopaminergic neurons within the basal ganglia leading to diminished motor function.

Parkinson's disease affects nearly 1.5 million Americans with treatment costs approximated at $25 billion annually. Currently, pharmacological and surgical treatment approaches to PD are largely symptom based, and the effectiveness of prescription medications decrease over time (29). Previously we have shown that a high-rate aerobic exercise intervention, or forced-exercise, is effective in improving global motor function and reducing symptoms in individuals with PD (1, 2, 32). Forced-exercise, is a mode of aerobic exercise in which an individual's cycling rate is mechanically augmented to allow for and maintain an exercise rate that is greater than their preferred voluntary rate of cycling. It is important to note, that during forced-exercise, the individual is actively contributing to the exercise, and not passively moving through the motion. Due to positive results from previous exercise research, there is an increased need to translate these findings from a laboratory setting to the PD community at large.

With any exercise program, it is important to have a simple and reliable method of monitoring exercise intensity (16). Community and outpatient based exercise settings do not always have access to the technology and equipment needed to directly monitor heart rate. The lack of easy and widespread methods of heart rate monitoring in community settings necessitates the need to identify simple, yet reliable and accurate, methods of evaluating levels of exertion during exercise screening and monitoring. The importance of effective and reliable monitoring of heart rate is of particular concern as PD patients exhibit a greater incidence of autonomic dysfunction that can result in abnormal cardiovascular responses (27). It is estimated that more than 20% of PD patients display characteristics of idiopathic orthostatic hypotension, with common symptoms including dizziness, lightheadedness and fainting, as well as abnormal systolic blood pressure responses to physical exertion (30), and those with PD display blunted heart rate responses during submaximal and maximal exercise when compared to healthy controls (22). The cardiovascular dysfunction in PD may not support the use of tools (i.e. ratings of perceived exertion scales) that healthy populations use to monitor exercise intensity, unless these tools are validated against a physiological response to exercise, such as heart rate. With the increasing body of literature that reports the benefits of aerobic exercise for PD, the mode in which exercise intensity is monitored needs to be validated in the PD population.

There are multiple ways to monitor exercise intensity, with the most commonly used being heart rate and RPE. Ratings of perceived exertion scales, such as those developed by Borg, are tools that are often utilized to monitor and quantify individual's perceptions of effort during exercise (7) and are used in exercise recommendations (28) as RPE is positively related to heart rate (5, 7). Different variations of these scales have been shown to provide valid and reliable estimates of physiologic measures of effort assessed during exercise in healthy children and adults (7, 34, 40). The validity of RPE scales in healthy populations has been established primarily by assessing the relationship between RPE score and physiologic measures of effort, such as heart rate, during an exercise test that incrementally increases in workload (7, 34). Linear increases in RPE can be seen as workload increases (5). A strong relationship has been reported for the association between RPE and heart rate in healthy adults (7). With strong positive correlations and the simplicity to administer, RPE is frequently used in clinical exercise testing as well as rehabilitation and recreational fitness settings (28, 40). While RPE scales have been validated in multiple contexts and populations, the validity of their use with in individuals with PD for exercise has not been evaluated.

Despite the lack of validity of RPE in PD, RPE scales are regularly used with this population (9, 23, 31). It is possible that the validity of the RPE scales may differ in the PD population as the cardinal symptoms of PD include tremor, bradykinesia, rigidity and postural instability, all of which contribute to altered neuromuscular control (13) and increase the level of overall daily effort and energy expenditure (25). In addition, about 40% of those with PD experience some sort of pain or discomfort as a result of their symptoms (12), which directly affects RPE scores (6), and coupled with the autonomic dysfunction of blunted heart rate response to exercise, altered RPE scores have been reported . Altered RPE scores in PD have been shown during submaximal aerobic exercise testing. Greater RPE scores have been reported in individuals with PD when compared to healthy controls at similar workloads (39). With increasing emphasis placed on the benefit of exercise for those with PD and unique challenges they face when exercising, it is necessary to determine the validity of the RPE scale in this population, particularly across different exercise intensities.

The aim of this project was to assess the validity of the Borg category ratio RPE scale, 0-10 scale, in a group of individuals with PD undergoing a graded maximal exercise test on a cycle ergometer. It was hypothesized that the RPE scores reported by those with PD would be associated with a physiologic measure of effort, heart rate, and exercise workload. As a secondary aim, disease severity, age and/or gender were assessed as possible mediators of RPE in those with PD during a maximal graded exercise test.

## METHODS

*Participants*

Thirty-eight males (n=26) and females (n=12) with a clinical diagnosis of idiopathic PD, who were rated as Hoehn and Yahr stage II-III (mild-moderate PD) when off anti-parkinsonian medication (approximately 12 hours off medication), completed exercise testing. Hoehn and Yahr is a commonly used disease rating scale that describes disease state (17). Participant characteristics and demographics are provided in Table 1.

**Table 1.** Participant characteristics. Data are mean ± SD.

| Variable | Females ($N$ = 12) | Males ($N$ = 26) |
|---|---|---|
| Height (cm) | 168.9 ± 7.3 | 178.1 ± 7.5 |
| Weight (kg) | 65.3 ± 10.2 | 86.5 ± 13.5 |
| Age (years) | 56.9 ± 5.5 | 58.7 ± 9.5 |
| $VO_2$ max (ml·kg$^{-1}$·min$^{-1}$) | 22.3 ± 5.7 | 25.0 ± 6.8 |
| Disease duration (years) | 3.73 ± 2.8 | 3.8 ± 2.5 |
| UPDRS III score | 20.0 ± 9.6 | 22.3 ± 8.3 |

All participants were recruited from the Cleveland Clinic or local neurology practices and were initially screened on the phone to ensure inclusion and exclusion criteria were met. Participants' medical history and physical examination were subsequently evaluated. Individuals with existing cardiopulmonary disease, diabetes mellitus, stroke, dementia, those on beta blockers or individuals with any medical or musculoskeletal contraindication to exercise were excluded. Prior to participation, all participants read and signed an informed consent document approved by the Cleveland Clinic Institutional Review Board.

*Protocol*

Participants made two visits to the laboratory for clinical and exercise testing. Clinical evaluation was completed using the Unified Parkinson's Disease Rating Scale Motor III (UPDRS-III) off anti-parkinsonian medication (approximately 12 hours) by a Movement Disorders Specialist. The UPDRS-III is the most commonly used clinical rating scale for PD (18).

Exercise testing took place within seven days after their first visit on their anti-parkinsonian medication. Participants were asked to undergo a graded maximal oxygen uptake ($VO_2$max) exercise test (GXT) completed on a cycle ergometer (Lode Excalibur Sport with Pedal Force Measurement, Lode B.V., Groningen, Netherlands). Participants reported to their exercise test appointment having fasted from food and drink, except water, for four hours and caffeine for at least 12 hours. Height and weight were recorded (Seca 644, Hamburg, Germany) and medical history was reviewed.

Prior to exercise testing, participants were familiarized with the cycle ergometer, standard 12-lead electrocardiogram (ECG) and Borg category ratio RPE scale which were to be utilized during the testing protocol. ECG (Welch Allyn, Cardioperfect, Skaneateles Falls, NY) was monitored throughout the entire graded exercise test (GXT), with blood pressure and RPE being assessed during the last 15 seconds of every stage. Although heart rate was monitored continuously, the heart rate that was used for comparison to RPE was taken during the last 15 seconds of each stage.

The GXT preformed was a modification of previously described protocols used in the PD population (8, 36). Participants began the exercise test with a five-minute supine rest prior to the warm-up phase of the GXT. The warm-up phase consisted of three minutes cycling at 20W resistance at a self-selected pedaling cadence. Participants were encouraged to keep this self-selected cadence throughout the GXT. After warm-up, each stage lasted two minutes in duration with 20W increases up until stage four (minute eight) when 40W increases were made until volitional exhaustion, or until the American College of Sport Medicine test termination criteria was met (38). After test completion, three minutes of recovery cycling at 20W was completed by each participant. $VO_2$ was recorded throughout the protocol via indirect calorimetry with averages being taken at 30 second intervals using a calibrated metabolic cart (Medgraphics Breeze Suite 6.1B, Minneapolis, MN) with each participant being fitted with a mouthpiece and nose clips.

*Statistical Analysis*
Concurrent validity of the Borg category ratio RPE scale was assessed by determining the relationships between RPE scores and heart rate and RPE scores and exercise workload using both univariate correlation analyses (*r*) and mixed effect models. Previous research has identified a strong positive correlation between heart rate and $VO_2$ (20, 37). Because these two measures of physiologic effort are strongly related it is not surprising that the correlation between both heart rate and $VO_2$ to RPE are typically similar (3, 20, 21, 33, 34). Because of this similarity we elected to assess only the relationship between heart rate and RPE. A two-step process was implemented to address the primary aim of whether RPE scores were associated with heart rate and exercise workload. First, univariate coefficients were calculated for each participant by individually correlating their RPE scores from each completed exercise test stage with the corresponding heart rates and exercise workloads using Pearson correlation analyses. The coefficients from all participants were then averaged and reported as mean correlation coefficients for the relationships between RPE and heart rate and RPE and exercise workload. Statistical significance from the correlation analyses could not be determined because each subject had multiple scores in the data set, which violates the assumption of independent scores. Therefore, mixed-effects models were added as a second step to the analysis because these models allow for multiple observations and interdependence of the observations within participants. Specifically, mixed-effects models were utilized to determine the significance of the associations between RPE and heart rate (beats $\cdot$ $min^{-1}$) and between RPE and workload (Watts) with the dependent variable (RPE) and the independent variables (workload and heart rate) with subject number as a random effect.

The models for heart rate and workload are illustrated below:
$RPE = \alpha + \beta_1$ (heart rate)
$RPE = \alpha + \beta_1$(workload)

In a subsequent analysis, linear mixed effect models were used to address the secondary aim of whether the RPE varied significantly as a function of age, sex, and/or disease severity (measured by UPDRS III scores) at exercise intensities that are typically prescribed to subjects in exercise programs (i.e. moderate- vigorous physical activity) (28). This process consisted of determining each participant's total range of exercise workload and heart rate values between stage 1 and their final stage. Next, the workload and heart rate values that corresponded to the 25%, 50%, 75% and 100% of the total range for each value were determined. Percentages were used in attempts to normalize the data since all participants did not progress to the same stage during their GXT. Because these exact values may not have been tested directly, a standard linear interpolation process was used in order to find the corresponding RPE values (henceforth called Lerp RPE). Lerp RPE scores at the various percentages of the total range of workload and heart rate values were the dependent variables. Independent variables of age, sex and disease severity were transformed into categorical variables to gain insight on how each variable may be contributing to the RPE scores. Age had three categories (young: 42-52 (n=9), average: 53-62 (n=15) and old: 63-72 (n=14)), gender had two categories (female (n= 12) and male (n=26)), and disease severity had 3 categories (least affected: UPDRS III score 1-12 (n=5), average: UPDRS III score 13-26 (n=19), and most affected: UPDRS III score 27-37 (n=12)). Groupings of UPDRS scores were established to define groups that had a difference of ~11 points between their maximum numbers. This number was selected based on previous research that has shown that a difference of ~11 points on the UPDRS motor score is a large clinically important difference (35) and would therefore have the best chance of segregating the groups into distinct levels of motor function. Exercise workload (a value of 25%, 50%, 75, or 100%) was the final independent variable and subject number was a random effect. The model for $RPE_{\%\ of\ total\ HR}$ is shown below (this model is the same for $RPE_{\%\ of\ total\ workload}$): Lerp $RPE_{\%\ of\ total\ HR} = \alpha + \beta_1$ [22] + $\beta_2$ (sex) + $\beta_3$ (disease severity) + $\beta_4$ (exercise workload) + all interactions.

In each model, when appropriate, the linear mixed effect models were simplified to reduce the number of predictive variables. This simplification was carried out in an automated fashion by application of the 'step AIC' function of the MASS library in R (15) which implements a selection based on Akaike's Information Criterion. This procedure searches for the model with the smallest number of variables that still minimizes the error in predicting the Lerp RPE. The statistical significance of the variables selected by the automatic search was confirmed using a type III ANOVA in order to account for an unbalanced data set. Once the model for each parameter (heart rate and workload) was identified through the automated selection process, the focus was narrowed to assess whether these factors where predictors at 50% and 75% of the total range of heart rate or workload. Typical exercise recommendations for intensity range from 50-80% of maximum heart rate (14), and the chosen 50 and 75% falls within that range.

**RESULTS**

Bivariate correlation analysis demonstrated a positive relationship ($r$ = 0.61, $p<0.001$) between heart rate and RPE (Figure 1) and a strong, positive relationship ($r$ = 0.77, $p<0.001$) between workload and RPE scores (Figure 2).

The linear mixed effect models confirmed the validity of using the RPE scale in a Parkinson's disease population by showing heart rate was a significant predictor of the RPE score ($p<0.001$) and workload was a significant predictor of the RPE score ($p<0.001$).

Results from the linear mixed effect models did not find evidence that age, disease severity, and/or gender, or the interactions of these factors, were significantly related to RPE scores at 50% and 75% of the subjects' total range of workload and heart rate values ($p>0.05$ for both workload and heart rate).

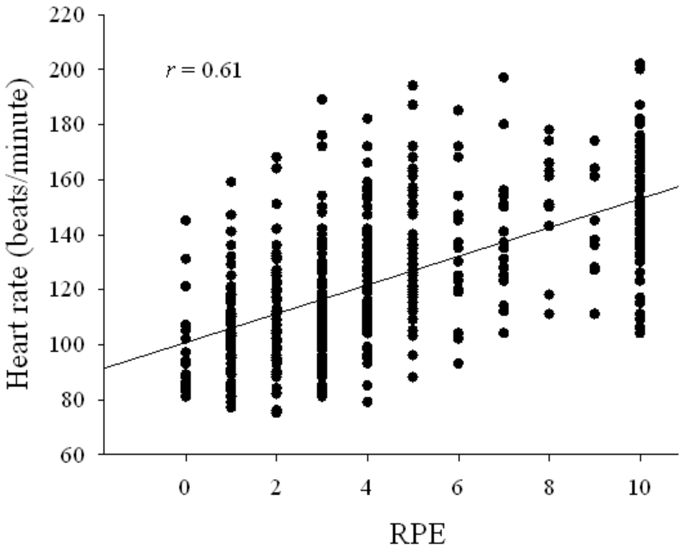


**Figure 1.** Association between RPE and heart rate (beats·min-1). There was a significant positive association between RPE and heart rate as determined by mixed-effect model ($p < 0.001$).

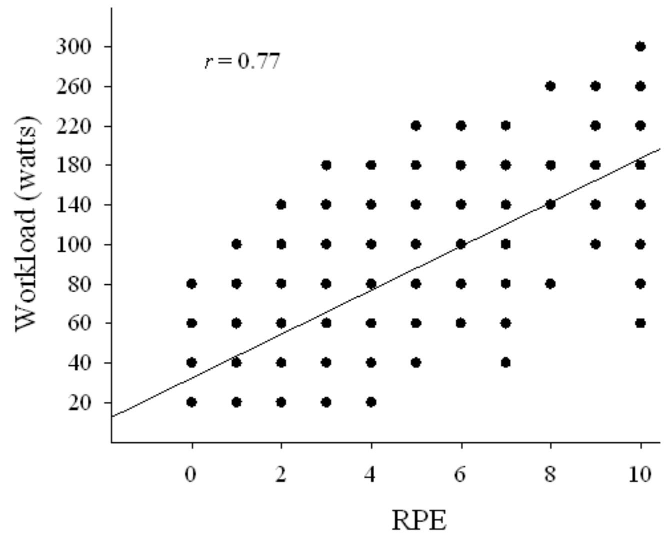


**Figure 2.** Association between RPE and workload (watts). There was a significant positive association between RPE and workload as determined by mixed-effect model ($p < 0.001$).

## DISCUSSION

The use of the Borg RPE scale is a widely utilized tool in clinical settings with exercise intensity control and prescription (10). Emerging evidence supports the utilization of exercise as an adjunct to pharmacological and surgical interventions for PD (1, 4). If the benefits of exercise are to be realized by the greater PD population, a critical step in the translation to a community based setting is to determine if common RPE scales, such as the Borg category ratio RPE scale, are valid measures of exercise intensity that can be used in monitoring exercise intensity in an exercise screening process, in the prescription of exercise and potentially the monitoring of PD patients during exercise. A strong positive correlation was present between Borg category ratio RPE measures and heart rate for those with mild to moderate PD. Therefore, the Borg RPE scale has concurrent validity with a physiological measure of exertion (heart rate) and workload in individuals with PD undergoing a maximal GXT regardless of age, disease severity or sex.

The validation of an RPE scale in a PD population has become increasingly important as the benefits of aerobic exercise for those with PD continues to emerge (1, 11, 19, 32). For example, in our studies we have shown up to a 35% improvement in upper extremity motor function after an eight-week lower extremity cycling intervention (1, 32). Others have also shown that cycling may improve symptoms of PD such as tremor and postural stability (24, 31). In addition to cycling, other forms of aerobic exercise have had beneficial outcomes in the PD population (19). Treadmill training programs have shown reductions in UPDRS scores (11) and improvements in gait parameters, such as stride length and walking speed (11, 26). The overall increase in exercise research and potential benefit to those with PD has led the need to validate simple methods of monitoring exercise intensity during exercise interventions. Validity of a RPE scales is helpful as the movement continues towards specific exercised-based recommendations for those with PD as a way to improve motor function.

While the present study shows a significant positive relationship between heart rate and RPE in people with PD, the correlation coefficient ($r$ = 0.61), it is lower than those reported in healthy populations ($r$ = 0.80-0.90) (7). This may indicate that people with PD may perceive a given workload as more difficult than those without PD due to the disease state, symptoms associated with PD, pain or autonomic dysfunction. However, our analysis did not reveal any evidence to suggest that age, gender or disease severity (as measured by the UPDRS III) significantly altered RPE scores. The results of this study suggest that the RPE scale can safely be utilized with valid results in a mild to moderate PD population regardless of age, disease severity or gender.

The present study was successful in validating the Borg scale in PD during a maximal GXT on a cycle ergometer. Effort ratings that closely follow heart rate responses serve as a simple, valid tool to monitoring exercise intensity when heart rate monitoring is not feasible. With the potential of aerobic exercise being a therapeutic intervention for those with PD, the findings from this study support the use of the Borg category ratio scale as an appropriate tool to help ensure those with PD are exercising at the proper exercise intensities.

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