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The validity of the GaitRite and the Functional Ambulation Performance scoring system in the analysis of Parkinson gait[1]

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Abstract. *Background and purpose:* The purpose of this study was (1) to determine the validity of the GaitRite System in detecting footfall patterns and selected gait characteristics of person with early stage Parkinson's disease (PD) and (2) to investigate whether the Functional Ambulation Performance (FAP) scoring system is a valid tool to distinguish between selected gait characteristics of patients with early stage Parkinson's disease and similar age of non-impaired individuals. The FAP score is a quantitative means of assessing gait based on specific spatial and temporal gait parameters.
Participants: 11 volunteers with idiopathic Parkinson's disease, (mean age = 74.3), and 11 age matched volunteers, (mean age = 70.3), with no history of neurological disorder participated in the study. The non-impaired control group were not matched in age and sex but of similar age and males and females were represented in the control group.
Methods: Temporal and spatial parameters of gait were analyzed for both preferred- speed and fast-speed walking using the computerized GaitRite system. The system integrates specific components of locomotion to provide a single, numerical representation of gait, the Functional Ambulation Performance Score (FAP) score.
Results: The most powerful and discriminating variable between Parkinson's and non-impaired groups for both walking speeds was the mean normalized velocity (MNV). Which is velocity divided by leg length. The MNV was 0.83 for PD at preferred walking speed and 1.14 at fast speed, the non-impaired group preferred-speed group walking was 1.33, while fast-speed walking MNV was 1.70. Note the fast walking of PD was slower than the preferred velocity of the non-impaired group. For preferred-speed walking, all gait variables analyzed in the study were different between the two groups beyond the $p < 0.05$ level of confidence with the single exception of right stance percentage. For fast-speed walking, three of the entered variables did not discriminate between the two groups: the fast walking FAP score, left fast-walking cadence, and right fast-walking single support percentage.
Conclusion and discussion: Our results indicate that persons with Parkinson's disease (PD) attain a significantly lower FAP score when ambulating at their preferred rate and demonstrate shorter step length and a longer step time than the age matched non-impaired group during both preferred and fast velocities of walking. Stance duration and double support duration were increased for the Parkinson's population, whereas single support duration, mean cadence, and heel-to-heel base of support were markedly reduced for both walking speeds. The FAP score was significantly different from the non-impaired control group for preferred-speed walking. These results indicate that the GaitRite system can be useful in detecting footfall patterns and selected time and distance measurements of persons with early stage Parkinson's disease and the FAP score discriminates between the PD population and the non-impaired controls when walking at preferred rate but not at fast walking.

Keywords: Parkinson, ambulation, GaitRite system, validity

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1. Introduction

Idiopathic Parkinson's disease is a chronic, degenerative disease of the basal ganglia which is characterized by a deficiency of dopamine within the motor control pathways of the brain [4]. Affecting both men and women equally, Parkinson's disease occurs in an estimated one million Americans [7]. One in every 100 persons over 65 years of age and 4 in every 100 persons over 80 years of age are diagnosed with Parkinson's disease [9].

The four salient features of the disease include bradykinesia or slowness of movement, rigidity, tremor, and postural instability [7]. The ability to initiate a movement, alter direction of movement, and stop a movement once it has begun is diminished [12]. These motor impairments lead to the characteristic gait pattern of Parkinson's disease which can be altered by instructions [2]. The trunk is flexed forward with excessive hip, knee and ankle flexion, arm swing is reduced, base of support is narrowed and there is a decreased range and velocity of movement [2]. Longer time is spent in the double limb support of the gait cycle, step length is reduced and there is a tendency to land at the end of the swing phase on a flat foot instead of with a heel strike, resulting in a shuffling gait [3].

Knuttson [10] reports stride length is reduced to 75cm in persons with Parkinson's disease as compared to 147cm in age matched controls. Basmajian [1] reports velocity is 0.56m/sec as compared to 1.36m/sec for controls, and cadence is reduced by approximately 25% in the early stages of the disease. Gait cycle time is increased in the person with Parkinson's disease, as is evidenced by 25% of the cycle time spent in double stance as compared to 11% in normal subjects [14].

Gait disorders constitute a major challenge for the person with Parkinson's disease. To accurately assess gait abnormalities, normal parameters must be used for comparison. Spivack [19] classifies some parameters of normal gait as including the following: a heel to heel base of support of 5.08 cm–10.16 cm, a 38.1 cm step length, and cadence of approximately 1.5 steps/sec-2steps/sec. During the gait cycle, the center of gravity oscillates approximately 5cm. in a vertical direction, the pelvis and trunk shift laterally approximately one inch to the weight-bearing side, and during the swing phase, the pelvis rotates 40 degrees forward. The knee should remain flexed in all components of the stance phase (except heel strike) to prevent excessive vertical displacement of the center of gravity [19].

Evaluation of gait is an integral component of patient evaluations, allowing the clinician to assess the degree of abnormality and to reassess the effectiveness of treatment [4,16]. There have been few quantitative studies of locomotor performance in persons with Parkinson's disease reported in the literature [3, 14]. Knutsson [10] examined the displacement patterns of walking in 21 persons with idiopathic Parkinsonism using intermittent-light photography. His results indicated a marked reduction in the mean velocity and stride length and an increase in the mean cycle time of the gait pattern of Parkinsonian patients, as compared to normal gait. Murray et al. [14] further used intermittent light photography to reveal that the Parkinsonian step length was significantly decreased for both free and fast speed walking as compared to age-matched controls. In 1990, Blin, Ferrandez, and Serratrice used an apparatus designed by Bessou et al. [3] to measure the longitudinal displacement of both feet during locomotion. A slower walking velocity, a shorter stride length, and a longer stride duration were observed in Parkinsonian patients as compared to age matched controls. Other findings reported by Morris and Iansek [13] revealed that the ability to modulate walking cadence is unaffected in Parkinson's disease. In addition, Murray et al. [14] found that groups with moderate to severe Parkinson's disease demonstrated no significant difference in cadence as compared to the control group. Other evaluation tools commonly employed in the analysis of Parkinsonian gait included videotaped observational gait analysis, electrogoniometry, and electromyography [18] and [19].

The need for reliable methods to assess spatiotemporal variables of the gait cycle is particularly important in the Parkinsonian population, because an altered footfall pattern is the hallmark symptom of Parkinson's disease [13]. The Functional Ambulation Performance (FAP) scoring system which was developed by Nelson [15], integrates selected time and distance parameters to provide a single, numerical representation of gait in adults. The score provides a quantitative means of assessing gait without the subjective qualification that most rating scales require. The FAP score is comprised of the linear relationship of step

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length/leg length ratio to step time when the velocity is "normalized" to leg length in healthy adults. The FAP score ranges from 95–100 points in the healthy adult population [15]. The FAP score is a valid, reliable, and objective method of measuring various gait parameters in both the hemiparetic and healthy populations, as established by Nelson [15]. The Reliability of the GaitRite System of FAP scoring was reported by Gretz, H.R., Deoring. L.D., Quinn, J., Raftopoulis, M., Nelson, A.J., Zwick, D. 1998. The FAP scoring system proved to be reliable with down And non-impaired age matched sample in Gretz et al. [8] researchers with an objective means for assessing the specific gait characteristics, step length/leg length ratio, step time, and mean normalized velocity, of adults with Parkinson's disease and other neurological disorders can be measured and compares favorably to other kinematic approaches [11].

The purpose of this study is twofold:

1. To determine the validity of the GaitRite System in detecting footfall patterns and selected gait characteristics of persons with early stage Parkinson's disease, walking at preferred and fast velocities, and
2. To investigate whether the FAP scoring system is a valid tool to distinguish between selected gait characteristics of persons with early stage Parkinson's disease and age matched non-impaired elderly adults walking at a preferred and fast velocity.

The researchers hypothesize that:

1. There will be an increased step time, double support percentage, and stance phase percentage of persons with Parkinson's disease as compared to persons without Parkinson's disease when instructed to walk at a fast walking speed.
2. There will be a decreased step length, cadence, and simple support percentage of persons with Parkinson's disease as compared to persons without Parkinson's disease during preferred speed and fast speed walking.
3. There will be a difference between the heel to heel base support, mean normalized velocities (mnv), and FAP scores of persons with Parkinson's disease and persons without Parkinson's disease during preferred speed and fast speed walking.

2. Research design

2.1. Subjects

Eleven (11) volunteers with idiopathic Parkinson's disease, 8 males and 3 females (mean age = 74.3), and eleven aged matched volunteers, 4 males and 7 females (mean age = 70.3), with no history of neurological disorder participated in the study. Individuals with Parkinson's disease were classified as stage I–III as per Hoehn and Yahr [9] Disability Rating Scale. No alterations were made in participants' normal medication cycles. All participants were tested within an average of 2.5 hours following their last dose of medication.

2.2. Instrumentation

Temporal and spatial parameters of gait were studied using the GaitRite System, a computerized instrument consisting of a 4.6 m electronic walkway with sensors arranged in a gridlike pattern to identify footfall contacts. The system integrates selected time and distance parameters to provide a single, numerical representation of gait in the form of ratios based on leg length FAP score. In addition, the computer records the following components of locomotion, including cadence, step time, step length, mean normalized velocity, step length ratio, heel to heel base of support, single support and double percentage and stance percentage.

2.3. Procedure

Prior to participation in the study all procedures were explained to the participant, informed consent was obtained and a general health questionnaire was completed by each volunteer. Two designated members of the research team measured bilateral leg length with a fabric tape measure from the superior border of the greater trochanter to the floor, bisecting the lateral malleolus [8].

Participants were instructed to walk at their preferred walking speed across the carpeted GaitRite mat with the verbal cue of "begin walking". Participants began ambulating 3 ft. before the walkway and continued for 3 ft. beyond the walkway. A total of 3 trials were performed, the first of which was a practice trial. Participants wore their own preferred walking shoes. One member of the research team walked alongside the participant, beside the electronic walkway during all walking trials for safety precautions. A brief rest period was allotted between walking trials.

Table 1
Right foot variables related to preferred walking patterns in patients with Parkinson's disease compared to a non-impaired control group

Variable	Patients with Parkinson's disease $N = 11$	Non impaired individuals $N = 11$	λ	F
Step extremity ratio				
Mean	0.51	0.76		
SD	0.12	0.16	0.51	18.94*
Step length (cm)				
Mean	45.12	64.14		
SD	11.32	12.30	0.58	14.23*
Step time (sec)				
Mean	0.65	0.57		
SD	0.06	0.05	0.67	9.62*
Heel to heel base of support (cm)				
Mean	12.99	9.65		
SD	2.87	4.18	0.80	4.75*
Single support %				
Mean	32.33	37.98		
SD	2.89	6.13	0.72	7.65*
Double support %				
Mean	33.06	27.32		
SD	4.76	3.66	0.67	10.06*
Stance %				
Mean	65.69	63.07		
SD	2.21	4.16	0.85	3.40

$^{*}p < 0.05$.

Table 2
Left foot variables related to preferred walking patterns in patients with Parkinson's disease compared to a non-impaired control group

Variable	Patients with Parkinson's disease $N = 11$	Non impaired individuals $N = 11$	λ	F
Step extremity ratio				
Mean	0.52	0.74		
SD	0.11	0.12	0.49	20.48*
Step length (cm)				
Mean	46.04	62.51		
SD	10.62	10.27	0.59	13.68*
Step time (sec)				
Mean	0.63	0.56		
SD	0.08	0.06	0.80	4.88*
Heel to heel base of support (cm)				
Mean	13.20	9.45		
SD	2.83	4.24	0.77	5.95*
Single support %				
Mean	33.77	36.85		
SD	2.42	3.40	0.77	5.96*
Double support %				
Mean	33.04	27.99		
SD	4.17	2.68	0.64	11.37*
Stance %				
Mean	67.54	62.65		
SD	2.92	4.62	0.69	8.79

$^{*}p < 0.05$.

3. Results

In order to test the hypothesis that there would be a significant difference in the gait of persons who had Parkinson's disease and the age non-impaired matched control group, several indicators of gait were collected on 11 persons who had Parkinson's disease.

Figure 1 presents the results for the discriminate analysis for preferred velocity of PD and non-impaired controls. In Fig. 1 the most powerful and discriminating variable between Parkinson's and non-impaired groups was the mean normalized velocity (MNV) ($\lambda = 0.43, p < 0.01$) Table 3, followed by left step extremity ratio (STEPER) ($\lambda = 0.49, p < 0.01$) (Table 1), right step extremity ration (RSTEPER) ($\lambda = 0.51, p < 0.05$), right step length, (RSL) ($\lambda = 0.58, p < 0.05$) (Table 1), and left step length (SL) ($\lambda = .59, p < 0.05$) (Table 2). In addition the FAP score was significantly different in the PD vs non-impaired control group ($p < 0.05$) (Table 3).

All variables in the equation were significant $p < 0.05$ level of confidence with the single exception of right stance percentage (RSP) (see Table 1).

Table 3
Preferred walking patterns in patients with Parkinson's disease compared to a non-impaired control group

Variable	Patients with Parkinson's disease $N = 11$	Non impaired individuals $N = 11$	λ	F
Mean normalized velocity				
Mean	0.83	1.33		
SD	0.19	0.26	0.43	26.74**
Cadence (steps/min)				
Mean	95.65	105.88		
SD	9.25	9.24	0.75	6.73
Functional ambulation performance score				
Mean	77.91	94.18		
SD	14.25	2.68	0.66	10.43*

$^{*}p < 0.05$; $^{**}p < 0.01$.

The discriminant function derived from the predictor variables had a Wilks' lambda cofficient of 0.11, which meant that is accounted for 89% of the variance between Parkinson's and non-Parkinson's groups. The Chi-square of the equation was 26.29, with 16 degrees of freedom, which was significant at the $P < 0.05$ level. When the cases were distributed along the dis-

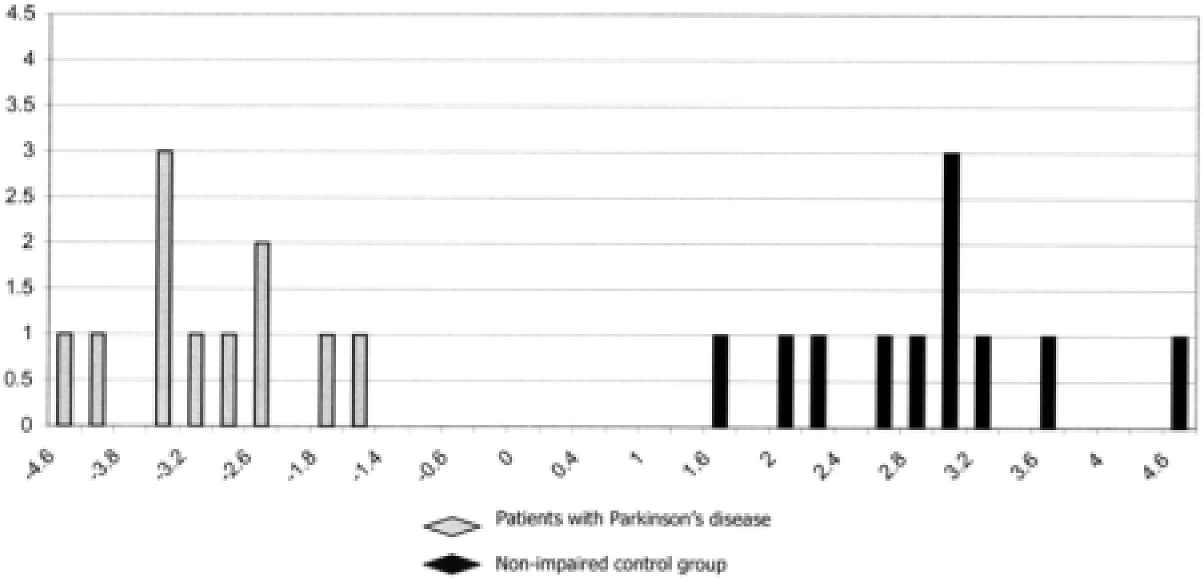

Fig. 1. Comparison of functional ambulation performance score in patients with Parkinson's disease compared to a non-impaired control group at preferred velocity ($N = 11$ for both groups)

criminant function, all 11 persons having Parkinson's disease were located on the negative side of the continuum and all 11 non-impaired subjects were on the positive side of the continuum (Fig. 1).

Table 4 presents the results of the fast walking trials. The results were quite similar in PD group to the results of the non-impaired walking trials. The most powerful discriminating variable between Parkinson's and non-Parkinson's groups was fast- walking mean normalized velocity (FWMNV) ($\lambda = 0.44, p < 0.01$) (Table 6), followed by right fast-walking step length extremity ratio (RFWSTEPER) ($\lambda = 0.50, p < 0.01$), (Table 4) left fast-walking step extremity ratio extremity ratio (FWSTEPER) ($\lambda = 0.52, p < 0.01$) (Table 5), right fast-walking stance percentage (RFWSP) ($\lambda = 0.60, p < 0.01$) (Table 4) right fast-walking step length ($\lambda = 0.65, p < 0.01$) (Table 5), and left fast-walking step length (FWSL) ($\lambda = 0.65, p < 0.01$) (Table 5). Three of the entered variables did not significantly discriminate between the two groups: fast-walking FAP, left fast-walking cadence, and right fast-walking single support percentage.

The discriminant function derived from the predicator variables had a Wilks' lambda coefficient of 0.04, which meant that it accounted for 96% of the variance between Parkinson's and non-impaired groups. The chi-square of the equation was 40.06, with 16 degrees of freedom which was significant at the 0.01 level. When the cases were distributed along the discriminate function, all 11 persons having Parkinson's disease were located on the negative side of the continuum and all

Table 4
Right foot variables related to fast walking patterns in patients with Parkinson's disease compared to a non-impaired control group

Variable	Patients with Parkinson's disease $N = 11$	Non impaired individuals $N = 11$	λ	F
Step extremity ratio				
Mean	0.59	0.81		
SD	0.11	0.12	0.50	19.61**
Step length (cm)				
Mean	53.03	68.83		
SD	11.96	10.37	0.65	10.96**
Step time (sec)				
Mean	0.53	0.49		
SD	0.06	0.05	0.85	3.47
Heel to heel base of support (cm)				
Mean	12.91	9.37		
SD	3.01	3.82	0.77	5.81*
Single support %				
Mean	35.62	38.05		
SD	2.92	2.76	0.83	4.04
Double support %				
Mean	28.37	24.06		
SD	3.82	3.98	0.75	6.70*
Stance %				
Mean	64.78	62.30		
SD	1.51	1.64	0.60	13.61**

$^{*}p < 0.05$; $^{**}p < 0.01$.

Table 5
Left foot variables related to fast walking patterns in patients with Parkinson's disease compared to a non-impaired control group

Variable	Patients with Parkinson's disease $N = 11$	Non impaired individuals $N = 11$	λ	F
Step extremity ratio				
Mean	0.61	0.82		
SD	0.12	0.12	0.52	18.13**
Step length (cm)				
Mean	54.19	69.45		
SD	11.88	10.22	0.65	10.14**
Step time (sec)				
Mean	0.53	0.48		
SD	0.05	0.05	0.81	4.61*
Heel to heel base of support (cm)				
Mean	13.22	8.86		
SD	3.23	3.58	0.68	9.04**
Single support %				
Mean	35.47	37.79		
SD	1.51	3.02	0.79	5.17*
Double support %				
Mean	28.93	23.92		
SD	3.63	3.92	0.67	9.65**
Stance %				
Mean	65.14	62.08		
SD	2.80	1.94	0.69	8.82**

$^{*}p < 0.05$; $^{**}p < 0.01$.

Table 6
Fast walking patterns in patients with Parkinson's disease compared to a non-impaired control group

Variable	Patients with Parkinson's disease $N = 11$	Non impaired individuals $N = 11$	λ	F
Mean normalized velocity				
Mean	1.14	1.70		
SD	0.21	0.30	0.44	25.48**
Cadence (steps/min)				
Mean	114.26	125.43		
SD	12.43	13.43	0.83	4.10
Functional ambulation performance score				
Mean	90.18	87.64		
SD	8.96	13.92	0.98	0.26

$^{**}p < 0.01$.

11 non-impaired subjects were on the positive side of the continuum (Fig. 2).

Our results indicate that persons with Parkinson's disease ambulate at a slower mean normalized velocity than age-matched non-impaired controls 0.83 $\pm$ 0.19 PD preferred velocity (Table 3) versus 1.33 $\pm$ 0.26 for non-impaired controls ($p < 0.01$) (Table 3) and at fast velocity of walking the persons with PD had MNV of 1.14 $\pm$ 0.21 (Table 6) and controls were MNV of 1.70 $\pm$ 0.30. When people with PD walk at their preferred velocity they had a mean stance duration of 67.54% versus a 62.65% for non-impaired control group. Similarly the PD group double support phase was 33% while the control group was 27.9% when walking at preferred velocity. The people with PD increased their MNV from preferred to fast walking (0.83 to 1.14 or an MNV increase of 0.31) while the controls increased from (1.33 to 1.70 for an increase of 0.37). Stance duration and double support duration were increased for the Parkinson's population, whereas single support duration, mean cadence, and heel to heel base of support were increased for both walking speeds as compared to control group. A shorter step length and a longer step time were observed in persons with Parkinson's disease during both walking speeds. The base of support in the PD group was 12.99 (right) (Table 1) plus 13.20 (left) versus non-impaired control group base of support (BOS) of 9.65 (R) and 9.45 (L) (Tables 1, 2) when walking at their preferred rate the patients with disease Parkinson's demonstrated the same increased BOS (12.91 R, 12.22 L) versus control 9.37 R and 8.86 L (Tables 4, 5).

The data indicate that for normal walking and for fast walking, the variables successfully discriminated between patients with disease Parkinson and non-impaired groups. Most of the differences were enhanced in the fast walking trials than in the preferred walking velocity trials.

4. Discussion

The decreased cadence observed within the Parkinson's population, during both preferred and fast speed walking, may be attributed to diminished step lengths taken in a relatively longer period of time [14]. These gait characteristics may be directly related to the inability of patients with disease Parkinson to generate large steps quickly enough as the PD group revealed an increased step time which is a direct manifestation reflecting the bradykinesia of Parkinsonism [10].

The mean FAP score for the patients with group Parkinson population improved considerably during fast walking as their preferred-speed walking was 77.9, and the age- matched control's FAP was 94.8 the PD fast speed walking FAP score was 90.1, while the age matched control's FAP was 87.64). This finding can be attributed to the fact that improvements occurred in the

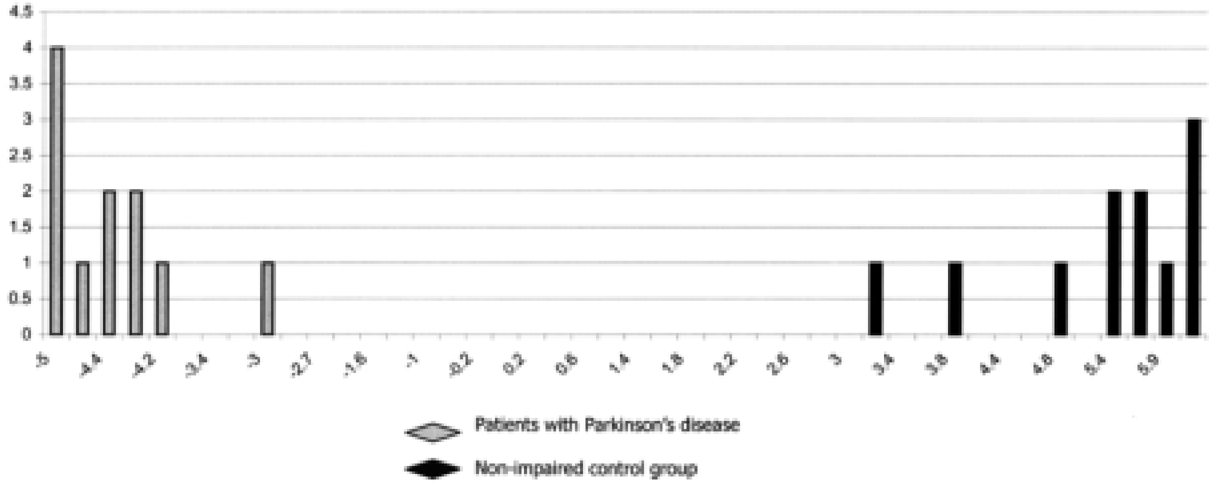

Fig. 2. Comparison of functional ambulation performance score in patients with Parkinson's disease compared to a non-impaired control group at fast velocity ($N = 11$ for both groups)

individual components that are velocity dependant and contribute toward the FAP score. The six factors included in the FAP score are all velocity dependent and as the persons velocity increases they will get higher scores for the composite. The increase in velocity of the PD group was from 0.83 to 1.14 or 0.31 versus 1.33 to 1.70 for non-impaired control increase of 0.37 (Table 3).

In accordance with the findings of Murray et al. [14] and Blin et al. [3], the researchers noted that a correlation may exist between the velocity of walking and the performance of Parkinsonian gait. Simply instructing the patients to walk at a faster pace resulted in improvement of many of the gait characteristics measured and in the overall quality of the participants' gait. The improvement observed during faster walking may be attributed to the fact that fast walking is driven by conscious motivation, suggesting that the healthy basal ganglia is involved in subconscious actions [6,12].

5. Conclusion

The purpose of the study was to evaluate the validity of the GaitRite and FAP Scoring System as a clinical tool to access the locomotion performance of person's with Parkinson's disease. The results indicate that the FAP score has the potential to provide clinicians with a standardized, objective means to evaluate gait abnormalities within the Parkinsonian population. Futhermore, the GaitRite System provides a more detailed analysis of the individual components of gait. These tools can assist clinicians in implementing, monitoring, and reassessing effectiveness of treatment plans in conjunction with pharmacological intervention for persons with Parkinson's disease.

The present study was limited in its applicability to a broad population of persons with Parkinson's disease, as only persons with early stage Parkinson's disease were tested. Futhermore, as the study was conducted while participants followed their usual medication cycles, the effects of medication on the gait cycle must be considered. Recommendations for future research and testing a larger sample size, testing each Stage within the Hoehn and Yahr classification system reference and analyzing the Relationship between the FAP score and the effect of medications on Parkinsonian gait.

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