The Effect of Secondary Task Performance on Gait in Parkinson's Disease Subjects

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ABSTRACT

Difficulty performing two tasks at the same time is one of the characteristic features in Parkinson disease (PD).The aim of this study was to investigate the effects of secondary motor tasks on the spatial and temporal parameters in 15 subjects with PD compared with 15 control subjects. Fifteen meters (m) gait laboratory walkway was used to compare footstep patterns when they walked; (1) freely, (2) carrying a tray, and (3) carrying a tray with four plastic glasses. Gait speed, stride length, cadence, and the percentage of the gait cycle in double limb support were measured. For all of the walking conditions, subjects with PD walked more slowly and with short steps than control subjects. There was little deterioration in gait when subjects in either group carried a tray and four plastic glasses.
Key words: *Gait, Parkinson disease, Rehabilitation.*

INTRODUCTION

Many people need to perform more than one task at a time during walking such as communication between people, transportation of objects from one location to another, and monitoring of the environment. Gait disturbance has been shown in people with Parkinson disease (PD)[1]. Subjects find that when they focus attention on one task, the performance of another becomes troublesome[1,2]. The magnitude of gait deterioration is thought to be proportional to the complexity of the secondary motor task being performed[3,4]. The second task becomes slow and difficult to sustain, and in some cases cannot be performed at all[6,7].

Physical therapists should know whether the type of secondary task affects gait so that they can educate patients with PD about likely consequences and risks of performing motor or cognitive activities while walking[8].

Most of the evidence for impaired dual task performance in people with PD has come from studies of upper-extremity performance[1,16]. Talland and Schwab2 studied people with and without PD during tasks requiring them to press a counter with one hand while they transferred beads with the other hand. They also assessed sequential (unitask) performance of these actions. Although, both groups showed reduced movement speed in the dual task condition. Those with PD showed a much greater performance decrement.

Similarly, Dalrymple-Alford et al.,[9] studied the effects of adding a cognitive task (digit recall) when subjects performed an upper-extremity tracking task. Subjects without PD were able to maintain similar levels of skill on the tracking task while recalling the digits. Subjects with PD increased the number of tracking errors when they focused their attention on reciting the digits. Based on previous research, therefore, people with PD appear to have difficulty performing simultaneous upper-extremity motor tasks as well as motor tasks coupled with cognitive tasks.

The dual task interference effects seen in the studies of upper-extremity performance may not necessarily apply to gait. Arm and hand movements are mainly controlled by the motor cortical regions, whereas locomotion is thought to be regulated mainly at brain-stem, spinal, and cerebellar regions, with descending input from the cortex[10,13]. Gait consists of highly preprogrammed movements, whereas some upper-extremity movements are more novel and are thought to require attention, visual guidance, and somatosensory feedback to control their performance[14,15].

There are a few explanations for why people with PD experience troublesome dual task interference. First, central processing resources become depleted because of degeneration of neurons of the substantia nigra pars compact in the brain stem and consequent dopamine insufficiency[11]. Because dopa-mine is one of the main neurotransmitters used by the basal ganglia in the control of well learned, sequential actions, the ability to perform these goal-directed tasks without undue attention is compromised. Second, there is some evidence to suggest that the basal ganglia-frontal cortex-basal ganglia feedback loops play a critical role in regulating movement automaticity[11]. According to Iansek and Coworkers12mention that, when two tasks are performed at the same time one usually runs at a subconscious level through the basal ganglia while the person attends to the other, which is controlled by the frontal cortex. If the basal ganglia are defective then the automatic task becomes slow, reduced in amplitude, or ceases altogether. The presence of external cues enhances performance presumably by focusing the person's attention on movements or thoughts that would otherwise be subconscious and by allowing the movements to be controlled by neural networks within the frontal cortex[13,16].

The aim of the study was to compare the ability of nondemented subjects with PD and age-matched control subjects to perform dual motor tasks while walking. Previous studies on dual task performance in PD mainly investigated upper limb laboratory tasks, such as finger tapping, isolated limb movements, and pursuit tracking tasks that bear little relation to the complex motor skills performed in everyday life. Therefore, to enhance the ecological validity of this study, gait performance was examined for three goal-directed tasks of everyday living with increasing levels of complexity. These tasks were (1) free walking, (2) walking carrying a tray, and (3) walking carrying a tray with four plastic glasses.

SUBJECTS AND METHOD

Subjects

Fifteen male subjects with idiopathic PD; mean age=55.3 years, SD=5.6, range=40-60), and 15 comparison subjects matched for age, sex, and height (mean age=56.7 years, SD=6.1, range=40-60) were recruited from the Riyadh Complex Medical Centre, Riyadh, Kingdom of Saudia Arabia.

Subjects were diagnosed by a neurologist, and they have no other neurological, orthopedic, or cardiovascular conditions that affected their walking. The Inclusion criteria were: 1)Subjects who had idiopathic PD, 2)Able to walk 15 meters (m) unassisted 10 times,3)They also had to score greater than 20 out of 38 on the Short Test of Mental Status (STMS) 17 and be able to provide informed consent. The STMS is a cognitive impairment scale, and scores less than 21 indicate dementia; The STMS assesses memory, dementia, planning, and problemsolving difficulties. The mean STMS score was 30.5. The subjects with PD were also assessed on the Modified Webster Scale; The Modified Webster Scale has 12 items that rate impairment and functional capacity. Higher scores indicate greater impairment.

Instrumentation

A clinical stride analyzer (CSA) was used to measure the spatiotemporal (time and distance) variables of footstep patterns, because it has been shown to provide some reliable measurements when repeat tests are performed with a 30-minute interval between tests (intraclass correlation coefficients were .95 for gait speed and .97 for stride length) for subjects with PD. 18 The CSA consisted of a set of inner soles with footswitches attached via leads to a data recorder worn around the subject's waist. The inner soles had 4 pressure-sensitive footswitches (one each for the heel, great toe, and first and fifth metatarsal heads) that were activated as the subject walked. For each 10-m gait trial the data logger stored information on the average stride length (length of two consecutive steps), cadence (steps per minute), gait speed, and percentage of the gait cycle spent in double limb support and The dual task interference paradigm utilized a tray-carrying task in conjunction with walking. The tray was plain, flat, and wooden, and measured 50 X 40cm and weighed 0.2kg. Four small crosses were marked 15cm from each corner edge to identify the positions of the glasses. The four glasses were identical, clear plastic, and long-stemmed, and weighed less than0, 01kg each. The glasses were 170mm tail, with a base 65mm in diameter.

Procedure

All testing was conducted in the Gait Laboratory at Riyadh Medical Complex Centre. Prior to testing, all subjects were interviewed about their medical history and had the research procedure explained to them. The STMS 17 was completed, and measurements of height, weight, and leg length were taken. Subjects with PD also were examined using the Modified Webster Scale, which provides a measure of disability[19]. Subjects with PD were tested during the self-determined peak or "on" phase of their medication cycle. This has been performed because greater consistency of gait performance has been demonstrated for people with PD when medication levels are optimal[18].

The subjects were tested on a 15-m gait laboratory walkway covered in grey linoleum, the middle 10m of which was sampled for data collection. The walkway was cleared of any equipment or obstacles at least 3m from each side. It is known that people with akinesia often experience an exacerbation of their motor blocks in cluttered environments[20]. The footstep pattern for each subject were measured in three conditions: (1) preferred walking ("free"); (2) walking carrying the tray ("tray"); and (3) walking carrying the tray with the empty glasses placed on top of the crosses ("glasses"). The order of presentation of conditions was stratified across the subjects to minimize series effects. The instructions for each test condition were as follows: (1) "Walk at a comfortable pace right to the end of the walkway." (2) "Walk at a comfortable pace right to the end of the walkway carrying this tray in front of you with both hands," (3) "Walk at a comfortable pace right to the end of the walkway carrying this tray and glasses in front of you with both hands ".To obtain representative samples, each test condition was repeated three times and the means of the three trials were used for further data analysis.

Statistical Analysis

Repeated measures analysis of variance (2 groups x 3 tasks). Selected post-hoc analyses using t tests with Bonferroni adjustments21 were used to analyze differences between the PD and control groups for gait speed, stride length, cadence, and double limb support duration across the all walking conditions (free, tray and glasses).

RESULTS

Table (1) and (2) contain the means and standard deviations for the three walking conditions for the Parkinson disease group and control group.

Table (1): Means and standard deviations for the three walking conditions in the Parkinson disease group.

Variables	Free	Tray	Tray/Glasses
Gait Speed (m/min)	67.15±10.23	66.01± 10.01	61.49±11.81
Stride length(m)	1.25±.20	1.22±.21	1.15±.25
Cadence (steps/min)	108.24±8.97	108.90±9.16	107.46±8.87
Double support (%)	31.72±6.91	33.40±8.34	33.52±5.89

Table (2): Means and standard deviations for the three walking conditions in the control group.

Variables	Free	Tray	Tray/Glasses
Gait Speed (m/min)	80.15±9.13	79.84± 8.01	78.39±7.81
Stride length(m)	1.36±.15	1.35±.14	1.33±.16
Cadence (steps/min)	109.33±4.82	109.70±5.64	109.95±6.38
Double support (%)	34.27±6.89	33.47±7.34	32.92±6.58

Gait speed

Planned comparisons showed a statistically significant difference in gait speed between free walking and walking with a tray and glasses in the PD group ($p = 0.009$& $\alpha = 0.025$), but no such difference in the control group ($p = 0.115$, $\alpha = .024$). Both groups demonstrated only negligible slowing in gait speed when shifting from walking freely to walking and carrying a tray (table 3 and fig 1).

Table (3): Comparison between gait speed of Parkinson disease and control groups across the three walking conditions.

Walking Conditions	PD Group	Control Group
Free	67.15±10.23	80.15±9.13
Tray	66.01± 10.01	79.84± 8.01
Tray/Glasses	61.49±11.81	78.39±7.81

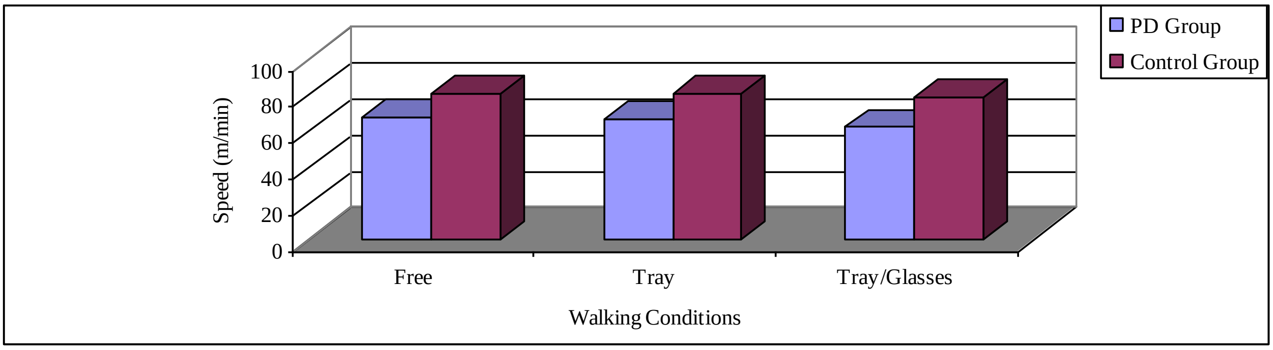

Fig. (1): Comparison between gait speed of Parkinson disease and control groups for the three walking conditions.

Stride Length

The changes from free walking to walking with a tray were negligible in both groups (tables 1 and 2). The interaction effect occurred because there was a significant reduction in stride length from free walking to walking with the tray and glasses in the PD group (P = 0.003, α = 0.025), compared with only minor changes in the control group (P = 0.178,α=.025) (table 4 and fig 2).

Table (4): Comparison between stride length of Parkinson disease and control groups across the three walking conditions.

Walking Conditions	PD Group	Control Group
Free	1.25±.20	1.36±.15
Tray	1.22±.21	1.35±.14
Tray/Glasses	1.15±.25	1.33±.16

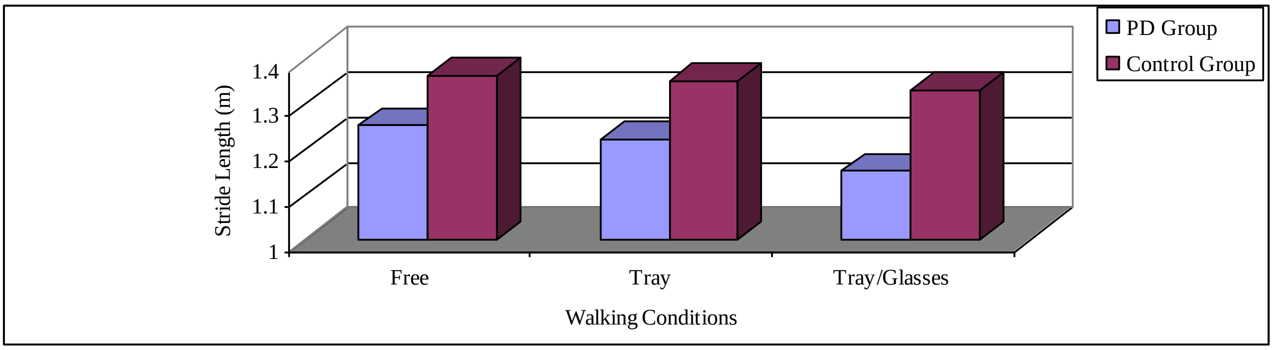

Fig. (2): Comparison between stride length of Parkinson disease and control groups for the three walking conditions.

Cadence

There was little change in walking cadence across any of the conditions in either group (tables 1 and 2). Moreover, planned comparisons did not reveal any change in cadence from free walking to walking with a tray and glasses in the PD group (P =0.114, α = 0.025), or control group (P=0.382, α = 0.025). Of note, in this study the mean cadence for the PD group for free walking (108.6 steps/min) The normal cadence in healthy older people (112 steps/min)[21].

Double limb support

Subjects with PD showed double limb support values for free walking equal that were (31.72±6.91), while it was (34.27±6.89) for the control subjects of the gait cycle. The recorded double limb support values for healthy people 65 years of age is usually 30% to 35% of the gait cycle.27 It was not surprising, therefore, that ANOVA did not reveal a significant interaction between group and condition (p = 0.81). Planned comparisons did not reveal any change in double limb support from free walking to walking with a tray and glasses in the PD group (P = 0.129, α = .025) or control group (P = .354, α = .025).

DISCUSSION

In agreement with previous studies, the present study showed that people with moderately disabling PD walk slowly, with short steps and relatively normal cadence when asked to walk freely at a comfortable pace[4,23,24].

Subjects with PD showed double limb support duration similar to that shown by control subjects. This finding may indicate that subjects in this sample did not have postural instability, which is usually compensated for by increasing the proportion of the gait cycle in which both feet arc in contact with the ground. Although subjects with PD could easily perform a simple goal-directed task (carrying a tray) without compromising their gait, they experienced considerable difficulty when required to perform an attention-demanding, complex, goal-directed task (carrying a tray with glasses) at the same time as walking.

Dual Task Interference

Subjects in the PD and control groups showed similar rates of deterioration in the footstep pattern, when a simple task was performed at the same time as walking, yet markedly different rates of change when performing a complex task. There is an agreement with many studies on motor skill performance in PD[4,25]. The previous studies have shown that performance of simple movements remains relatively unaffected by PD, yet when simple movements have to be incorporated into complex, skilled actions they are performed more slowly[4,11,25,26,27,28] or with greater error[27,28,29] than before.

The basal ganglia play a key role in controlling well-learned skilled movements, when these movements have been practiced to the stage where they can be executed "automatically," with little thought or attention[24]. Positron emission tomography studies have shown that during the early stages of motor skill acquisition, and for novel or ballistic movements, the motor cortical regions predominate in motor control[30]. With repeated practice the control of skilled movements is relegated to the cortical-basal ganglia-cortical feedback loop, which leaves the cortical regions free for higher-order information processing. This means that a person does not need to closely attend to a movement as it is executed and can divert attentional resources to other motor or cognitive activities. In PD the neurotransmittcr imbalance that arises in the basal ganglia as a result of a reduction in dopaminergic neurons disrupts the motor functions of the basal ganglia. It can be suggested that as a compensation patients rely more heavily on frontal cortical regions and "on-line" visual, proprioecptive, and auditory input to consciously control and guide movements, and bypass the defective basal ganglia[4,24,31]. The shortcoming of this type of compensation is that it is resource-demanding and leaves patients with little in reserve when they need to perform an additional task at the same time as they arc attending to the primary task.

Contrary to the present study predictions, increasing the complexity of the secondary task did not produce a statistically significant reduction in gait speed, stride length, and cadence or an increase in the proportion of the gait cycle spent in double limb support in the elderly control subjects, probably because the secondary tasks were relatively easy, highly familiar, well learned, and performed routinely many times every week by elderly people. Although Talland and Schwab2 demonstrated that elderly people performed more slowly than younger adults in dual tasks, they obtained this result from the performance of novel reaction time tasks of considerable difficulty.

Models of Dual Task Interference

The main theoretical models accounting for dual task interference in people with PD are: (1) the capacity- or resource-sharing model, (2) the bottleneck model, and (3) the cross-talk model (see Pashler[32] for a detailed review). These are "attentional" models, with the term "attentional" referring to the focus of mental activity on a task. Capacity-sharing models are based on the assumption that attention resources are limited. Therefore, when people perform two tasks simultaneously, attention must be divided between the tasks. How attention is divided between the two tasks relies on several factors, including task complexity, familiarity, and importance.33 According to the capacity-sharing model, dual task interference will occur only if the available resource capacity is exceeded, resulting in a decline in performance on one or both of the tasks[33].

The bottleneck and cross-talk models assume that dual task interference is affected by the type of tasks performed simultaneously, rather than the amount of attention needed to sustain performance[33]. According to the bottleneck model, similar tasks performed concurrently cause "bottleneck" interference because they compete for the use of the same pathways[33]. In contrast, cross-talk models assume that task similarity reduces dual task interference, because the use of the same pathway increases the efficiency of processing by using less attention resource capacity[33].

The present study findings indicated that subjects with PD experienced the most difficulty when performing the pair of tasks that were least similar (walking and carrying a tray with glasses), lending some credence to the cross-talk model . Gait changes occurring during dual task situations may be the result of compensations undertaken by people with PD to reduce the risk of falling. Fast walking speeds require greater balance control because of the rapidly changing accelerations of the center of mass and the reduction in double support time[34]. The slow walking speed and reduce stride length during secondary tasks in people with PD may be attempting to decrease the balance requirements for gait. Paradoxically, slow walking speeds also can increase balance demands because greater time must be devoted to balancing the head, arms, and trunk over the stance leg[34]. Increases in double support time are thought to negate this effect during slow walking[34]. In the present study, comparison subjects who were instructed to walk at their preferred speed demonstrated an increase in their double support time in the dual task conditions, which may indicate that they were able to accurately compensate for the reductions in stride length and walking speed. In contrast, subjects with PD in other studies did not increase double support times during dual task performance when walking at their preferred speed. This can be explained as these results may indicate that people with PD have an impaired ability to modulate double support to compensate for the reductions in stride length and walking speed. This impaired ability may increase the risk of falls.

Clinical Implications and Limitations

The major goal of physical therapy for people with PD is to help them walk with normal step size and speed in order to reduce the risk of trips and falls.34 The results of the present study have several implications for gait rehabilitation in subjects with PD. First, it appears to be important for clinicians to evaluate the effects of dual task performance on walking at regular intervals after PD has been diagnosed. If a deficit is detected, then patients should be alerted to the deterioration in walking that can occur when complex secondary motor tasks are attempted while walking. When dual task interference is severe, patients should be taught methods of avoiding more than one action at a time whenever possible. For example, patients could be instructed to carry lightweight objects in a backpack rather than in their arms, and to maintain a focus on walking with large steps rather than letting the mind wander while walking[4,5] studies by Soliveri and colleagues35 suggest that mildly disabled people with PD may be able to learn new upper limb tasks to (he stage where they can be retained and transferred to other conditions. Whether this applies to locomotion is yet to be investigated. Therefore, it is advisable to teach people with PD about the safety risks associated with doing more than one task at a time. Some therapists might argue that teaching people with PD about the safety risks associated with simultaneous task performance should include engaging them in other tasks during gait training, while they are under close supervision. Whether people with PD have the capacity to learn how to perform dual tasks during walking safely and independently has not been established. Research is also needed to determine whether people with PD can learn how to safely and independently switch from doing several tasks to only walking when needed. Although these results contribute to the movement sciences literature, some limitations must he acknowledged. First, a relatively small sample of moderately disabled patients with PD, as there is only limited generalizability of findings to the population of people with PD as a whole, only nondemented subjects were recruited; therefore, these findings may not apply to people with moderate to severe cognitive impairment, which occurs in approximately 30% patients with end-stage disease[36]. Second, to fully understand the effect of secondary motor task performance on gait in subjects with PD, the effects of various types of skilled, unskilled, complex, and simple tasks need to be evaluated. Comparisons of the effects of secondary tasks requiring habitual attention and conscious attention would assist in understanding how subjects with PD are able to direct and allocate their attention. Analysis of the effects of a wider range of motor and cognitive tasks on parkinsonian gait may also assist in clarifying the role of the basal ganglia in movement execution. Finally, the reasons why some secondary tasks, such as listening to rhythmical music[l5,38] or stepping over while lines on a floor,[4] act as external cues that facilitate walking in subjects with PD, while other secondary tasks compromise walking, have not been addressed and require further consideration.

Conclusion

The results of the present study add weight to the growing body of literature showing that people with PD have difficulty performing several tasks at once. When subjects with PD attend to a complex secondary motor task at the same time as walking there is marked dual task interference that compromises the speed of walking and the size of the footsteps. These results support previous work that has demonstrated that people with PD have difficulty performing two tasks concurrently. For this reason, it is important that the effects of dual task performance on walking be evaluated at regular intervals after diagnosis. It is also important that physical therapists educate people with PD about the difficulties that can occur when a complex motor skill is performed at the same time as walking and teach them strategies to cope with these difficulties.

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الملخص العربي

تأثير أداء عمل ثانوي آخر على المشي لدى مرضى الشلل الرعاش

إن صعوبة أداء عملين في نفس الوقت من الخصائص المميزة للشلل الرعاش. والهدف من هذا البحث هو دراسة تأثير القيام بعمل ثانوى على قياسات المشى وذلك في خمسة عشر مريض بالشلل الرعاش مقابل خمسة عشر شخص صحيح.وقد تم أخذ القياسات لهذه الحالات الثلاثة : (1) المشي الحر(2)المشي مع حمل صينية خشبية (3) المشي مع حمل صينية خشبية عليها أربعة أكواب بلاستيكية . وتمت القياسات الآتية للمشي:سرعة المشي، طول الخطوة، معدل الخطوات في الدقيقة الواحدة والنسبة المئوية من المشي أثناء وجود القدمين على الأرض . وأظهرت نتائج البحث أن الأشخاص المصابين بالشلل الرعاش يمشون ببطء وبخطوات قصيرة عن الأشخاص الأصحاء. بينما كان التأثير طفيفا على قياسا ت المشي لدى الأشخاص المرضى و الأصحاء مع حمل صينية خشبية عليها أربعة أكواب بلاستيكية .