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Research Article

Biomechanical analysis of Sit-To-Walk movement in Parkinson's patients

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Abstract

Aim: The aim of this study was to evaluate the ankle-knee-hip interaction during sit-to-walk (STW) movement and clinical functional abilities of the lower limbs in Parkinson's patients.

Methods: Twenty male patients, ages ranged from 55 to 70 years, stage II & III according to modified Hoehn and Yahr (1997) classification of disabilities and ten male healthy elderly subjects, ages ranged from 55 to 70 years, participated in this study. All subjects were assessed for; clinical functional abilities of the lower limbs, ground reaction force (GRF) & spatiotemporal data and range of motion (ROM) of hip, knee and ankle joints during STW movement.

Results: The results showed very significant differences in the GRF among the normal subjects and Parkinson's patients during STW movement. There were significant differences in hip, knee and ankle joints ROM during STW. There were significant differences in spatiotemporal findings during STW movement. The Parkinson's disease patients did not merge the two tasks of STW while the elderly subjects merged it. There was impairment in clinical functional abilities of the lower limbs in Parkinson's patients.

Conclusion: A continuum of STW performance and clinical functional abilities whereby the healthy elderly people performed the task more efficiently than PD patients.

Introduction

Parkinson's disease (PD) is a chronic progressive neurodegenerative movement disorder defined by the presence of tremor, rigidity and bradykinesia [1].

Postural instability during dynamic transitional movements such as rising from a chair is the cause of increased risk of falls. Falls are a characteristic feature of the disease progression leading to considerable morbidity and mortality. Transfers are so problematical in PD; leg weakness particularly at the hip explains a part of the difficulties experienced by PD patients' while attempting to rise from a chair. So, in PD the efficacy of strength training to improve transfers remains to be demonstrated for PD patients. Alternative strategies to improve transfers are available, including the chaining technique splitting complex movements up into a series of simple components that are to be executed sequentially [2].

Studying the transitions in movement such as sitting to standing, standing to walking or walking to running extends our understanding of human movement and offering valuable insight on motor control as well as risks of injury [3]. Two dynamic transitional movements, which challenge the postural stability of PD patients, are gait

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initiation (gi) and the sit-to-stand task (STS). Gait initiation is defined as an elegant sequence of postural shifts that culminates in a forward step. gi is challenging to the motor control system since it is a volitional transition from a static stable support to a continuously unstable posture during locomotion. Thus many investigators have utilized gi as an assessment of dynamic postural instability [4].

The study of gi and STS has been valuable in understanding dynamic postural stability within common activities of daily living (ADL). This is surprising since the initiation of gait from a seated position or sit-to-walk (STW) is a more common ADL and it represents a complex transitional task that imposes challenges to both the locomotor and postural control systems. The STW is more challenging than STS because forward momentum generated at seat off continues into the first step [5].

The purpose of this study was to biomechanically evaluate the STW task in PD patients and compare the dynamic stability of the PD patients to healthy aged matched subjects.

Patients and Methods

Twenty male Parkinson's patients as study group; Group I (GI), stage II & III according to modified Hoehn and Yahr (1997) classification of disabilities ,and ten male healthy elderly subjects as control group; Group II (GII) participated in this study. Patients were recruited from the neurology outpatient clinic at Kaser El Aini Teaching Hospital and the out-patient clinic, Faculty of Physical Therapy, Cairo University. The patients were diagnosed by a neurologist as having Parkinson's disease based on careful clinical assessment and radiological investigations including magnetic resonance imaging (MRI) of the brain.

Instrumentation

The data were collected through the use of: 1) Opto-electronic motion analysis system with a force plate unit; Qualisys Motion Capture System was used in this study to measure movements or excursions of the ankle, knee and hip joints; of the right lower limb in conjunction with a force plate unit; An Advanced Mechanical Technology Inc., USA (AMTI) to measure the ground reaction force (GRF) magnitude at hip, knee and ankle joints during two phases of sit-to-stand transfer in GI and GII.

Procedures

All patients were informed with the apparatus components and steps of analysis and participated in several trials with the equipment to assure them psychologically and to be familiar with the study. The study was conducted at the motion analysis Lab., faculty of physical therapy, Cairo University.

All patients were subjected to the following assessment:

Timed Up and Go (TUG) test

Task: By the command "Go", the subject stood from a standard chair, walked three meters, turned and walked back to the chair. Timing started when the command was given and ended when the subject sat again on the chair. The Timed Up and Go test and comfortable gait speed are highly correlated with locomotion abilities and autonomy in the elderly [6].

The repeated STS test

Starting from a sitting position, the subject was asked to stand up as fast as possible 5 times consecutively without using the arms for support while standing and sitting. The scores ranged from 0 (inability to stand up) to 4 depending on the time the subject took to perform the test.

Fall history score

Subject was asked about number of falls. The scores ranged from 1 (none) to 3 depending on the number of falls.

Assessment of foot-knee-hip interaction during changing of position from sit-to-walk (STW) in Motion Analysis Lab. This stage included:

i. Assessment of ankle, knee and hip joints range of motion (ROM) during four phases of STW movement by the use of 3-D motion capturing unit (Qualisys Motion Capture System).

ii. Assessment of GRF during two phases of STS movement by the use of force plate unit.

iii. Assessment of time of sit-to-walk movement.

iv. Measurement of spatial & temporal parameters during stand-to-walk movement.

Statistical analysis

Data was analyzed using IBM SPSS Advanced Statistics version 22.0 (SPSS Inc., Chicago, IL). All assessment variables were tested for normality of distribution (Shapiro-Wilk test). Unpaired t-test was used to compare the mean changes in the subject's parameters in between the two groups [7].

Results

The two groups were comparable regarding age, height, weight and body mass index (BMI) as shown in table 1. Table 2 shows mean values of TUG, RSTS and FHS for both groups: There was a highly statistically significant increase of TUG test (sec) (P=0.0005). There was a statistically significant decrease of RSTS test (P=0.0018). There was a statistically significant increase of FHS (P=0.0085).

Table 3 shows a statistically significant increase in mean values of ankle dorsiflexion (°) during STS movement. (P=0.0020), There was a statistically significant decrease in mean values of knee extension (°) during STS movement (P=0.0023), There was

Table 1: Demographic and clinical characteristics of the two studied groups.

M	Group I n=20	Group II n=10	p value
Age (years)	63.45±4.85	61.6±5.08	0.341
Height (cm)	170.55±10.12	170.9±7.84	0.925
Weight (kg)	78±17.69	80.67±13.16	0.678
Body mass index (kg/m^2)	26.56±3.91	27.44±2.85	0.533

Data presented as mean±SD.

Table 2: Mean values of TUG, RSTS and FHS for both groups.

	Group I n=20	Group II n=10	p value
TUG	16.15±3.98	11±1.25	0.0005**
RSTS	2.6±0.64	3.7±048	0.0018*
FHS	2±0.56	1.4±0.52	0.0085*

Data presented as mean±SD.

Table 3: The lower limb joints ROM.

	Group I n=20	Group II n=10	p value
Angle of ankle dorsiflexion	14.99±5.26	9.07±2.01	0.0020*
Angle of knee extension	69.4±5.63	76.87±5.97	0.0023*
Angle of hip flexion	38.1±4.12	28.19±5.41	0.0001**
Angle of hip extension	72.41±10.99	81.18±9.57	0.041*

Data presented as mean±SD

a highly statistically significant increase in mean values of hip flexion (°) during STS movement. (P=0.0001), while there was statistically significant decrease in mean values of hip extension (°) during STS movement (P=0.041).

Table 4 shows a statistically significant decrease in mean values of the peak vertical ground reaction force (N) during STW movement (P=0.0083), There was a highly statistically significant decrease in mean values of the peak anteroposterior ground reaction force (N) during STW movement (P=0.0003).

Table 5 shows a statistically significant increase in mean values of the phases' duration (seconds) of GI (compared to GII in STW movement during phases I, II, IV, and during total duration I (P=0.0079), II (P=0.0044), phase IV (P=0.0207), and during total duration (P=0.0009). While mean values of phase III was not statistically significant between, (P=0.1691).

Table 6 shows a highly statistically significant decrease in mean values of step length (m) and step velocity (m/s) during STW movement (P=0.0001), with a statistically significant increase in mean values of the time between seat off and heel off (seconds) of during STW movement (P=0.0045).

Discussion

This controlled randomized study was conducted to biomechanically evaluate the STW task in PD patients and compare the dynamic stability of the PD patients to healthy aged matched subjects. This study was conducted to evaluate foot-knee-hip interaction during STW movement and to evaluate clinical functional skills of the lower limbs in Parkinson's patients. The subjects were assessed clinically using timed up and go test, the repeated STS test and fall history, ROM of hip, knee, and ankle joints, ground reaction forces, spatiotemporal and duration of phases.

The introduction of time and distance measurement has enhanced the quality and objectivity of clinical tests for human function in the rehabilitation setting. For example the 6 min walking test [8] and the modified 10 m test [9].

Performance of STW movement, particularly in the elderly, is a challenging and risk laden movement. Measuring this movement in a clinical setting has the potential

Table 4: Mean values of peak vertical & anteroposterior GRFs (N) during STW movement for both groups.

	Group I n=20	Group II n=10	p value
VGRF	467.07±85.96	604.25±181.25	0.0083*
APGRF	161.47±19.58	273.27±79.50	0.0003**

VGRF: vertical ground reaction force, APGRF: anteroposterior ground reaction force. Data presented as mean±SD

Table 5: Mean values of STW phase durations (sec.) during STW movement for both groups.

	Group I n=20	Group II n=10	p value
Phase I	0.698±0.207	0.493±0.124	0.0079*
Phase II	0.794±0.247	0.537±0.118	0.0044*
Phase III	0.268±0.173	0.188±0.055	0.1691^{NS}
Phase IV	0.604±0.124	0.502±0.054	0.0207*
Total duration	2.81±0.679	1.97±0.312	0.0009*

Data presented as mean±SD

Table 6: Mean values of spatiotemporal data during STW movement for both groups.

	Group I n=20	Group II n=10	p value
Step length	0.42±0.1	0.58±0.06	0.0001**
Step velocity	0.67±0.18	1±0.2	0.0001**
Time between seat off and heel off	1.21±0.47	0.71±0.29	0.0045*

Data presented as mean±SD.

to identify patients with impaired mobility and the data can assist in planning and evaluating intervention [10]. Lastly, this study explained that the healthy elderly subjects performed the task more efficiently than the Parkinson's patients. The healthy elderly subjects appeared to merge the two tasks around seat off. However, the Parkinson's patients were unable to merge the two tasks into one continuous movement and they appeared to complete STS before performing gi. With respect to ROM of the ankle joint during STS movement, there was a statistically significant increase in mean values of ankle dorsiflexion (degrees) of GI compared to GII during STS movement. Rigidity of the plantarflexors and to less extent dorsiflexors makes this difference in addition to increased trunk leaning in GI as compared to GII. Besides, A-P sway is highest in Parkinson's patients due to lack of stability. And this also agree with Margaret who stated the increase of ankle dorsiflexion to control the increasing horizontal momentum and COM position during seat off, a strategy that provides better postural stability during STS movement [11].

Regarding ROM of the knee joint during STS movement, there was a statistically significant decrease in mean values of knee extension (degrees) of GI compared to GII during STS movement. While during phase II the lower value was in GI and the higher one in GII. Additionally, the results of the present study showed a small knee ROM during phase I, then the range increased during phases II and (finally decreased again at end of phase II for all groups).

During phase II, ROM of the knee joint in GI was smaller than GII. This might be explained as follows: the starting position of STS movement is 105° of knee flexion (for all subjects) and the knee joint ROM ends by reaching to full knee extension (ROM of the knee joint is limited because it is controlled by full knee extension). During phases I, the knee joint (in GI) moves a larger range than GII (due to loss of knee extensors strength and subsequently the remained ROM of the knee will becomes smaller in the second phase of STW movement in GI as compared to GII [12].

With respect to the ROM of the hip joint during STS movement, the results of the present study revealed that, there was a highly statistically significant increase in mean values of hip flexion (degrees) of GI compared to GII during STS movement. This might be justified as follows: during phase I, the patients make excessive trunk flexion to gain more momentum to compensate the weakness of the hip and knee extensors. There is a tendency to increase hip flexion to enhance horizontal momentum at the beginning of movement and this agrees with Margaret. This is in agreement with the opinion of Butler who postulated that an important part of a complex compensatory mechanism used by Parkinson's patients with gross muscle weakness; is full flexion of trunk in the early stages of rising [13]. With respect to the vertical GRF during STW movement, the results of the present study revealed that, there was a statistically significant decrease in mean values of the peak vertical ground reaction force (N) of GI compared to GII during STW movement. With respect to the anteroposterior GRF during STW movement, the results of the present study revealed that there was a highly statistically significant decrease in mean values of the peak anteroposterior ground reaction force (N) of GI compared to GII during STW movement and this agree with Corcos who demonstrated a deficiency in the rate of force production and this identify fallers in those patients [14].

Anteroposterior ground reaction force, there was an important propulsive impulsive during walking initiation. The point of transfer from a propulsive to a braking impulse in the AP direction in relation to seat-off was variable between subjects. The magnitude of peak AP GRF occurred at the beginning of unloading phase [15].

Walking requires initiation from a variety of positions and postures. Walking from seated is probably one of the most common of these tasks and yet STW has received little investigation. STW differs from STS in that the body continues to progress forward, requiring a propulsive force that was affected at PD subjects. This force may differ from STS to STW, not only at pushoff, but earlier. Investigating the propulsive forces may help in understanding clinical problems and guiding therapy [16].

With respect to the spatiotemporal parameters during STW movement, the results of the study revealed that; there was a statistically significant increase in mean values of the phases durations (sec.) of GI compared to GII in STW movement during phases I, II, IV, and during total duration. While in phase III, it was not statistically significant. The longer duration of the STW transfer was due to clinical progression of the disease, certain characteristic of the disease such as bradykinesia and difficulty in changing position and direction. However, the nonsignificance difference at phase III may be due to small sample size, or phase III; the most little phase of STW movement and difficult to measure.

Persons with PD are known to have limitations in proprioception, movement speed, muscular strength and reduced general mobility gives explanations of longer duration of STW transfer in GI compared to GII. So, the deteriorated performance during the STW task had been suggested to be related to impaired physical performance characteristics or to an altered movement strategy in individuals with postural instability like in PD [17].

With respect to the stepping characteristics during STW movement, the results of the present study revealed that, there was a highly statistically significant decrease in mean values of step length (m) and step velocity (m/s) of GI compared to GII during STW movement, with a statistically significant increase in mean values of the time between seat off and heel off (seconds) of GI compared to GII during STW movement. It was not surprising that the healthy elderly subjects produced the greater step velocity and step length when compared to those with PD.

The period between leaving the chair and the establishment of the gait pattern is particularly difficult, involving a rapid change in stability and change in movement direction which, at risk subjects may need to execute carefully avoiding large momenta which may be difficult to control or threaten their stability. This may explain the large drop in forward velocity in the elderly at risk of falls (EARF) after seat-off. This hesitancy during movement has been noted before in elderly populations [18]. While Parkinson's patients rose to near fully erect height and appeared to balance them before initiating gait. Vertical momentum at the time the swing foot left the ground was significantly less in PD compared to elderly ones, indicating that Parkinson's subjects had finishing rising prior to starting gait initiation [19].

The period between leaving the stool and the establishment of the gait pattern is particularly difficult, involving a rapid change in stability and change in movement direction which, at risk subjects may want to execute carefully, avoiding large momenta which may be difficult to control or threaten their stability.

Conclusion

This is the first study to assess the performance of PD patients during the STW motor task. In general, it was concluded that a continuum of STW performance whereby the healthy elderly people performed the task more efficiently than PD patients. Additionally, the PD patients were unable to merge the two tasks into one continuous movement and they appeared to complete the STS before performing gi. This was evident by the long delay between seat off and the initiation of gait. While the elderly people merged the two tasks (STS & gi) into one continuous movement.

These findings have potential implications in understanding the risk of falls in PD patients during dynamic transitional movements and can provide a structure for studying the STW motor task.

Clinicians can utilize this information to develop rehabilitation programs designed to address the specific deficiencies noted in this study. Physical interventions designed to improve physical and motor functioning such as resistance training to improve power, strength and stability.

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