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Biomechanical analysis of reaching pattern in patients with Parkinson's disease

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Abstract

Background: Understanding the mechanisms of underlying common motor deficits in Parkinson's disease patients is a major prerequisite for successful rehabilitation therapy. Objectives: the aim of this research was to see how different muscle activity amplitudes influenced active range of motion (ROM) and how much motor impairment affect the reaching pattern in Parkinson's disease patients. Methods: thirty male patients with Parkinson's disease participated in the study and 19 age-matched control male subjects. Their average age was 68.53±5.27 years old. The analysis was carried out while seated in a chair. The patients were directed to use their dominant arm to a target that was set within arm's reach in the forward horizontal plane. A three-dimensional motion analysis system was used to measure the range of motion of shoulder flexion, elbow extension and wrist extension. The deltoid, the lateral head of the triceps, and the radial wrist extensors all had their amplitudes of electromyography (EMG) registered. Results: In the dominant arm of patients with Parkinson's disease, there had been a substantial decline in EMG amplitudes of chosen muscles as well as ROM of shoulder flexion, elbow, and wrist extension, all of which have an impact on motor performance of the reaching pattern. Conclusion: In Parkinson's disease patients, a decrease in EMG activity amplitudes of chosen muscles was thought to be a major cause of limited ROM and increased levels of motor impairment in the reaching pattern.
Keywords: Parkinson's disease, EMG, 3-D Motion Analysis, Reaching Pattern

INTRODUCTON

Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects the substantia nigra's dopaminergic neurons. Reaching patterns are an important part of activities of daily living (ADL), and decreased hand function in Parkinson's disease may affect activities like eating and dressing [1].

The straightforward pendulum seems to be to classical biomechanics as reaching motions to motor function. While reaching movements are easy to understand, they are interesting to motor function researchers because they are supported by a wide range of motor brain areas. Reaching movements have diagnostic importance from a clinical standpoint because different motor disorders, such as Parkinson's disease (PD), show distinctive changes in reaching movements. Patients with Parkinson's disease are considered to have slower response times and movement times while performing simple goal- directed movements [2].

Diseases that affect upper-limb movement and postural control restrict this reaching movement. Several studies have identified the reaching movement of patients with Parkinson's disease (PD), and the recorded characteristics of their reaching movement involve a delayed initiation of movement, drowsy speed of motion, and poor coordination among the arm and the trunk [3].

Reduced mobility of the upper extremities owing to akinesia or bradykinesia, reduced flexibility attributable to rigidity of the four extremities and trunk, and weakness of postural reflexes correlated with these declines are thought to restrict reaching movement in Patients with PD.

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Furthermore, patients with Parkinson's disease were reported to have problems with eye movement and coordination among the eyes and head when reaching. [4].
The aim of our research is to see how altered muscle activity amplitudes affect active ROM and the extent of motor impairment in the reaching pattern in Parkinson's disease patients.

SUBJECTS AND METHODS

Thirty male patients with Parkinson's disease were selected from out-patient clinic of physical therapy, Prince Mutaib Hospital in Jouf, KSA. Their ages ranged from 60 – 75 years (Group A) and compared with 19 age-matched control male subjects (Group B). Inclusion criteria was as following: the duration of illness ranged from three to ten years after diagnosis by neurologist, with Hoehn and Yahr disease stage ≤3 and the Unified Parkinson's Disease Rating Scale (UPDRS) assessed by neurologists. They had sufficient cognition demonstrating to understand the requirements of the study; they had good eye-hand contact and had good postural stability in sitting. All cases were medically stable and assessed while on medications. Levodopa equivalent daily doses were noted [5].
Exclusion criteria: patients who had a cognitive impairment (MMSE; score ≤ 25) or had a neurological disorder other than Parkinson's disease, impairment of deep sensation, secondary complications such as contractures or deformities, and psychological problems.
Skin preparation for applying the surface electrodes was started. EMG recordings of the clavicular head of the pectoralis major, anterior deltoid, lateral head of the triceps brachii, and wrist extensors were made with bipolar surface electrodes. Patients were prepared for applying EMG electrodes over the selected muscles. The hair was shaved at picking up areas and then cleaned with alcohol 70% to remove the dead layer of skin at the area just below the clavicle, anterior surface of upper third of the arm, posterior surface of middle third of the arm, and dorsal surface of proximal third of forearm [6].
Three separate cameras were used to collect data from an Optotrak^{TM} opto-electronic three-dimensional movement recording system. At a sampling rate of 150 Hz, this system registered the three-dimensional (x, y, and z) locations of infrared emitting diode markers (IREDs) mounted on the hands and wrists. When moving at speeds similar to human arm movements, this system had a static positional resolution of, 0.5 mm across the entire experimental workspace and a dynamic spatial resolution of, 0.8 mm [7].
Patient's chest and upper limbs were bare; the markers were placed on the selected bony landmarks: the acromion process, the lateral epicondyle of the humerus, and the center of the wrist joint's dorsal aspect, the base of the middle finger, and the iliac crest. These markers were stabilized on skin by using double face adhesive straps and were checked to be visible to the six cameras.
The patient was asked to assume the erect posture while sitting on the chair with a right angle between the trunk and the thigh. Feet were well supported on the floor. A belt around his chest to render trunk movement, and avoid side leaning during movement. During the reaching movement of the arm, the movement should start with the starting beep and end with the ending beep of the 3-D motion analysis system. The time of motion capture was five seconds [8].
Each patient in the study group (A) was asked to reach forward by the dominant arm at his arm's length at 90° shoulder flexion level without moving the trunk. Patients could choose their own speed of movement but encouraged to perform the tasks in the same way, along of the three trials of reaching tasks and the motion saved on the computer and the mean of three trials was collected. The same procedure is done for healthy control subjects in the control group (B).

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Statistical analysis: Data examined by Shapiro–Wilk test for normality. To assess changes of myoelectric activities & ROM, parametric unpaired t-tests were performed. Analyses were performed at $P < 0.05$ [9]. Ethical statement: Our investigation protocol was approved by the Ethics Committee at Jouf University in KSA, and Ethics Committee of clinical trials.

RESULTS

This study was concerned with determining the impact of altered EMG muscle activity amplitudes on the shoulder joint flexion, elbow extension and wrist extension ROM during reaching pattern in patients with Parkinson's disease. Parkinson's disease Characteristics. Every item had a mean standard deviation (Mean ±S D) of 28.93 ±1.1 for the MMSE, 5.9 ± 3.3 years for disease length, 2.6 ± 0.7 for the Hoehn-Yahr scale, and 16.0 ± 9.5 for the UPDRS3. Table 1 shows sociodemographic characteristics.

Table 1. Parkinson's patients' clinical and demographic characteristics (group A) and healthy control subjects (group B)

	Group A n=30	Group B n=19	P value
Age (years)	68.53± 5.27	67.63±4.60	0.46
MMSE	28.93±1.1	28.72±0.9	0.35
Education (years)	14.1 ±3.34	14.7 ±3.43	0.55
Body height [cm]	177.46 ± 7.05	176.00 ± 6.01	0.47
Body mass [kg]	84.66 ± 17.05	77.30 ± 7.72	0.52

MMSE, Mini-Mental State Examination; The data is presented as mean ± SD.

The mean difference values between EMG amplitudes of clavicular head of pectoralis major and anterior deltoid muscles of the Parkinson's and healthy people upper limbs were statistically significant ($P = 0.000$). The mean difference value between the EMG amplitudes of Parkinson's and healthy people upper limbs was statistically significant ($P = 0.000$). The mean difference value between the radial wrist extensors EMG amplitudes of Parkinson's and healthy people upper limbs became statistically significant ($P = 0.000$) as shown in Table 2.

Table 2. Changes in mean values of myoelectric activities (mv) of dominant upper limb of both groups.

	Group A	Group B	P value
Clavicular head of pectoralis major	3.21±0.38	5.56±0.53	0.000*
Anterior Deltoid	5.19±0.61	7.62±0.63	0.000*
Lateral head of triceps brachii	2.78±0.51	4.69±0.82	0.000*

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Radial wrist extensors	1.88±0.21	3.28±0.42	0.000*

Values are significant at P < 0.05; The data is presented as mean ± SD.

There was marked decrease in the mean value of shoulder flexion ROM of the dominant upper limb in Parkinson's patients that was 66.60±7.28 degrees which revealed a statistically significant difference with its analogue in the healthy counterparts' upper limb that was 80.90±4.47 degree (P = 0.000). The mean difference value between elbow extension ROM of Parkinson's and healthy people upper limbs was a significant (P = 0.000). The mean difference value between the wrist extension ROM of Parkinson's and healthy people upper limbs was a significant (P = 0.000) shown in Table 3.

Table 3. Changes in mean values of range of motion (º) of dominant upper limb of both groups.

	Group A	Group B	P value
Shoulder flexion	66.60±7.28	80.90±4.47	0.000*
Elbow extension	134.23±6.09	147.73±4.21	0.000*
Wrist extension	20.20±3.89	27.73±2.19	0.000*

Values are significant at P < 0.05; The data is presented as mean ± SD.

The results showed that there was a moderate positive linear correlation between the EMG amplitudes of clavicular head of pectoralis major (r = +0.448, p = 0.013) and anterior deltoid (r = +0.414, p = 0.023) with the shoulder flexion ROM. The results indicated that there was a mild positive correlation between the EMG amplitudes of lateral head of triceps muscle and elbow extension ROM in Parkinson's dominant upper limb (r = +0.250, p = 0.355). The results indicated that there was a moderate positive linear correlation between the EMG amplitudes of radial wrist extensors and the wrist extension ROM in Parkinson's upper limbs (r = +0.544, p = 0.002) shown in Table 4.

Table 4. Correlation between myoelectric activities of upper limb and ROM in Parkinson's group.

	r	p
Clavicular head of pectoralis major	+ 0.448	0.013*
Anterior Deltoid	+ 0.414	0.023*
Lateral head of triceps brachii	+ 0.250	0.355

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Radial wrist extensors	+ 0.544	0.002*

Values are significant at $P < 0.05$; The data is presented as mean ± SD.

DISCUSSION

The current study aimed to investigate the effect of changed EMG muscular activity amplitudes on the active ROM of reaching movement and to describe the relationship of EMG amplitudes to the motor impairment of reaching pattern in patients with Parkinson's disease.

Patients participated in this study had a primary complaint of limited ability to execute reaching movements to targets placed within their affected arm's length. They had to use motor compensation to complete the reaching task which is the most critical component of fine motor skills needed in their ADL.

The most common reasons concerned with the difficulty of reaching movement in Parkinson's patients are mainly related to disrupted interjoint coordination and to abnormal torque production in the Parkinson's limb. Patients with Parkinson's disease are thought to have abnormal movement patterns which limit their capacity to control their joints in flexible and adaptive patterns, limiting their capacity to conduct several functional movements, according to health rehabilitation science. [10].

Our results agreed with Levin et al. who mentioned that excessive trunk displacement is a compensatory behavior caused by spared cortical and subcortical systems' efforts to compensate for lost control over motor functions including shoulder-elbow interjoint coordination and elbow extension. [11].

Patients with Parkinson's disease have slow, less precise, and indirect arm reaching movements. This is agreed with McCrea and Eng. who found that these changes could be linked to a reduction in motor commands through neuromotor pathways. Transmission ability could be described as a linear relationship among movement time and task complexity in tasks that require both speed and accuracy. Parkinson's disease results in decreased capacity to transmit motor commands, which has consequences for both motor execution and planning [12].

Poor performance of reaching movement in patients with Parkinson's disease might also be explained by the lack of appropriate force generation by the involved muscles. When the typical agonists engaged in a forward reaching task are unable to produce enough force, compensatory muscle recruitment strategies may be required to complete the task [13].

The number, the size and the frequency of activated motor units are reduced in the presence of hypertonia. Results of reduced EMG amplitudes on the arm explained the abnormalities of muscle activation which underlie the inability to coordinate muscle function when performing a motor task after Parkinson's disease, which was characterized by excessive biceps muscle activation, reduced triceps activation and muscle activation-target motion coupling [14,15].

Results of the current research revealed that, there was a significant reduction in the shoulder flexion, elbow extension and wrist extension ROM of the dominant upper limb when compared to the limb of healthy subjects. These results were mainly caused by different factors affecting the ROM as rigidity, muscle weakness, incoordination, abnormal postural control and soft tissue contractures or tightness. Our results of reduced ROM in the dominant arm are consistent with Hu et al. and Baziyan et al. who reported that, damage to the CNS causes tone abnormalities, which can affect range of joint motion and, in general, decrease speed of movement [16, 17].

Muscle weakness directly engaged in the movement might have induced limitations in active range. This agreed with Reisman and Scholz who reported that, the static and dynamic stretch reflex thresholds were decreased in Parkinson's patients compared to normal subjects, in addition to a reduction in the capacity to regulate stretch reflex thresholds in relation to the velocity of movement. This may explain the problems of force regulation as well as weakness and hypertonus common to these patients [18].
Results of this work revealed that, there was a significant correlation between EMG amplitudes of anterior deltoid and clavicular head of pectoralis major muscles with the ROM of shoulder flexion in Parkinson's patients' arm. The correlation between the lateral head of triceps muscle EMG amplitudes and elbow extension ROM was weak in the dominant arm, the correlation between EMG and ROM data of wrist extension was also significant.
From the mentioned discussion, the EMG activity amplitudes of the selected muscle in the dominant arm were reduced at the measured ROM and completely different from the normal pattern. Motor compensations used for the reaching pattern in the dominant arm in Parkinson's patients are mainly due to the reduced EMG amplitudes of the agonist muscles involved in the reaching movement. Weakness, hypertonicity, muscle imbalance, and are considered as the main causes of the decreased amplitude of the EMG muscle activities which in turn affects the active ROM and the level of motor impairment in patients with Parkinson's disease.

CONCLUSION

To conclude, the current research is the first to compare the kinematic patterning of reach-to-grasp movements in PD with that of age-matched healthy subjects in the hopes of uncovering potential upper-limb dysfunctions in this population. Both have bradykinesia, hypometria, and a lack of coordination among the reach and the grasp components. Patients with PD, on the other hand, are much less compromised than healthy subjects when it comes to the parallel execution of coordinated motor plans. In patients with Parkinson's disease, reduced EMG activity amplitudes in chosen muscles were a major reason of limited ROM and increased motor dysfunction in the reaching pattern.

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