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STRETCH-SHORTENING CONTRACTION IN PARKINSON PATIENTS: EVIDENCE OF NORMAL MUSCLE CONTRACTION EXECUTION WITH LOW EFFICIENCY

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ABSTRACT. The aim of this study was to compare different muscle contraction types in Parkinson patients and controls. Ten patients with mild to moderate Parkinsonism (7 men, 3 women, mean age 62.3) and 11 controls (7 men, 4 women, mean age 66.0) were investigated. Measurements in eccentric, concentric contraction and stretch-shortening contraction were made using modified Cybex 11 equipment. The torque areas in ankle dorsiflexors at 30°/second, 120°/second and 180°/second were measured. The power (Nm/second) was calculated in a defined range of motion. The power at different angular velocities and contraction types was significantly lower in the patient group than in the control group. In both groups the power in eccentric and stretch-shortening contraction was significantly larger than in concentric contraction. The relative improvement in power in stretch-shortening contraction in patients was equal to the improvement made by the controls. Patients generated significantly more EMG than controls in concentric and eccentric contractions. The EMG in the stretch-shortening cycle was the same in both groups at higher velocities. The patients performed voluntary isolated muscle contraction in the same way as controls, but with a lower efficiency in contraction. The eccentric torque and the supplement of torque generated from the combined eccentric and concentric (stretch-shortening) contraction might be important for achievement of adequate dynamic movements in patients with Parkinson's disease.

Key words: Parkinson's disease, contraction, concentric, isometric, eccentric, isokinetic, muscle, stretch-shortening.

INTRODUCTION

Muscles consist of contractile elements as well as passive elastic components. The passive elastic components comprise tendons and connective tissue. The contractile elements in muscles generate contraction, but also participate in the generation of muscle tone (3, 30) regulated by supraspinal centres. Muscle tone may influence motor function if it is increased (2, 5).

The muscle can be looked upon as a spring which can be stretched and recoils back to its original position when released, thus regenerating the energy deposited in the spring (3, 4, 11, 17).

Fast changes between different types of contraction are pertinent for execution of useful motor function. Descriptions of concentric and eccentric contractions have elucidated many interesting aspects of muscle function (27–29, 31, 32). If an eccentric contraction is immediately followed by a concentric contraction, the torque output in the following concentric contraction is increased in comparison with an ordinary concentric contraction (2, 8, 25). The improvement in torque is believed to be generated by the passive elastic elements. This so-called stretch-shortening (SS) cycle has previously been reported only in healthy subjects (25), but to our knowledge no such investigation has been made in patients with spasticity or rigidity.

The aim of this study was to describe the different contraction types, especially the stretch-shortening contraction in ankle dorsiflexors in Parkinson patients, and to compare the results with normal controls.

PATIENTS AND METHODS

Subjects

Ten patients (7 men and 3 women) with mild to moderate Parkinsonism (Hoehn & Yahr I–III, 12) participated in the study (mean age 62.3 years, range 56–69). The duration of disease was 3–6 years. All were on ordinary anti-Parkinson medication. Eleven normal controls (7 men, 4 women, mean age 66.0 years, range 64–69) also took part in the study. No medical, neurological or orthopaedic disease was reported in the control group.

Methods

A 5-minute warm-up on an ergometer bicycle was done before strength testing, with a load of 1 watt. Test subjects were placed sitting in a testing position as described by Öberg et al. (19, 20, 32). Only the left leg was tested. The testing was done using Cybex II equipment modified for recording eccentric contractions (32). Peak torque was recorded in the ankle dorsiflexors. Strength was tested at several angular velocities, 30–120–180 °/second. Subjects performed isolated concentric and eccentric contractions. The stretch-shortening cycle was tested by doing an eccentric contraction followed by a concentric contraction. Electromyographic (EMG) recordings over the muscle bellies of m. tibialis anterior and the lateral gastronemius were done using surface silver/silver chloride electrodes. Angular velocity, range of motion, torque and rectified integrated (RMS) EMG recordings (iEMG) were displayed on a fast paper writer (Gould 1000). Areas of torque and EMG were calculated using a Digitizer. A defined sector in the movement, calculated from a recording at 180°/second, with a range of 10 mm (18°) was chosen in order to describe also the amount of iEMG in the different contraction types.

The range was chosen in such a way that the peak torque value was within the range. This means that the size of the range was the same in all contraction types and angular velocities, but the measuring position could be different. Variations in peak angle are seen in different contraction types. In eccentric and concentric contraction the chosen measuring position was the same, but the position was different for the stretch-shortening contraction.

The power (Nm/second) was calculated.

Statistics

Results are presented as means and standard error of the means. For comparison between groups the Mann–Whitney test was used, and for comparison of paired results the Wilcoxon rank sum test was used. *P*-values below 0.05 were considered to be significant.

RESULTS

There were no differences between the groups in the distribution of sex, age, weight or height.

Concentric contraction

The power was found to be lower in patients ($p < 0.05$–0.001) than in controls at all velocities. At high-speed (180°/second in relation to 30°/second) concentric contraction the power was found to decrease relatively more in patients than in controls ($p < 0.02$). For results see Table I.

Eccentric contraction

The power of eccentric contraction was significantly lower in patients than in control ($p < 0.05$–0.001). The mean power increased with angular velocity in controls ($p < 0.04$), but in patients the increase was not significant (Table I).

Stretch-shortening cycle

The calculated power was smaller in patients than in controls ($p < 0.01$–0.001) at all velocities.

In both groups the power at 120°/second and 180°/second in the stretch-shortening cycle was significantly larger than the power of concentric contraction ($p < 0.01$). Power in the stretch-shortening cycle was significantly lower than in eccentric contraction at all angular velocities ($p < 0.01$) (Table II). The calculated power in stretch-shortening in relation to concentric power was the same in both groups.

Fig. 1 describes results from the different contraction types.

Table I. *The power of contractions. Data presented as means, with standard errors in parentheses; p < 0.05 is considered significant*

	Nm/sec		iEMG/sec.	
	Patients	Controls	Patients	Controls.
Concentric contraction				
30 °/sec.	1882 (621)*	2665 (928)	2158 (950)*	1380 (750)
120 °/sec.	918 (492)**	1600 (483)	1907 (906)*	1145 (500)
180 °/sec.	647 (403)***	1369 (439)	1564 (665)*	1016 (388)
Eccentric contraction				
30 °/sec.	2480 (743)**	3450 (753)	1934 (811)*	1221 (671)
120 °/sec.	2628 (1036)**	3862 (684)	2220 (971)*	1400 (764)
180 °/sec.	2833 (1315)*	3737 (1009)	2497 (559)**	1425 (802)
Stretch-shortening contraction				
30 °/sec.	1687 (843)*	2332 (793)	1649 (833)*	1147 (586)
120 °/sec.	1334 (687)**	2164 (630)	1353 (670)	1045 (408)
180 °/sec.	1161 (521)***	2171 (803)	1239 (687)	1171 (511)

Significance levels for differences between patients and controls: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

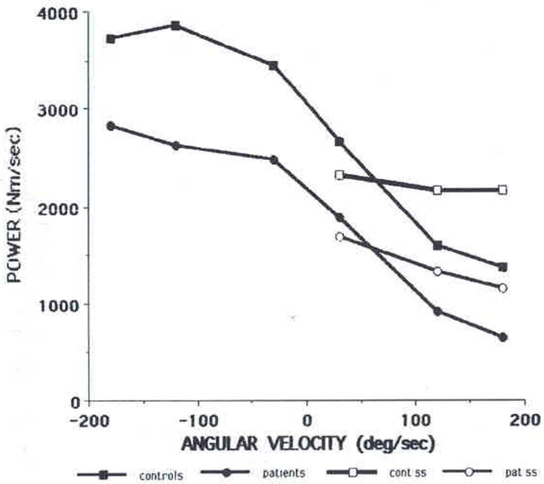

Fig. 1. Power velocity diagram showing the relationship between the calculated power and angular velocity in the eccentric, concentric and stretch-shortening contraction in patients and controls. SS indicates power in the stretch-shortening contraction in patients and controls. ■ = Controls; ● = patients; □ = cont ss; ○ = pat ss.

Table II. *The relationship between the different contraction types and angular velocities for power and EMG.*
E indicates eccentric contraction, C concentric contraction, SS stretch-shortening contraction; $p < 0.05$ is considered significant

	Controls		Patients	
	Contraction	*p*-value	Contraction	*p*-value
EMG				
30 °/sec.	SS < C	0.05	SS < C	0.05
	SS = E		SS = E	
	E = C		E = C	
120 °/sec.	SS = C		SS < C	0.01
	SS < E	0.01	SS < E	0.01
	E > C	0.02	E = C	
180 °/sec.	SS = C		SS = C	
	SS = E		SS < C	0.01
	E > C	0.02	E > C	0.001
Power				
30 °/sec.	SS < C	0.05	SS = C	
	SS < E	0.01	SS < E	0.05
120 °/sec.	SS > C	0.01	SS > E	0.01
	SS < E	0.01	SS < E	0.01
180 °/sec.	SS > C	0.01	SS > C	0.01
	SS < E	0.01	SS < E	0.01

Significance levels for differences between contractions: *$p <$ 0.05, ** $p < 0.01$, *** $p < 0.001$.

Electromyography

EMG areas in eccentric and concentric contraction at all angular velocities were found to be significantly larger in patients compared with controls ($p < 0.05$–0.01). In stretch-shortening contraction the EMG areas at 30°/second were larger in patients compared with controls ($p < 0.05$), but EMG did not differ between groups at 120°/second and 180°/second.

In controls, EMG areas in eccentric contraction were significantly larger than in concentric contraction at 120 °/second and 180°/second ($p < 0.03$). For patients this was found only at 180°/second ($p < 0.001$).

In the control group, the EMG areas in the stretch-shortening contraction were significantly smaller than the EMG areas in concentric contraction at 30°/second and eccentric contraction at 120°/second. In other angular velocities and contractions they were the same as in concentric and eccentric contractions. EMG areas in the patient group in the stretch-shortening contraction were significantly smaller than EMG areas in eccentric and concentric contraction at all velocities except for concentric contraction at 180°/second and eccentric contraction at 30°/second, where they were the same.

In neither group was antagonistic muscle activity recorded.

The differences in EMG areas between different types of contraction are shown in Table II.

Power/iEMG area

For all contraction types the power per integrated EMG area at all velocities was found to be smaller in patients than in controls ($p < 0.01$– 0.001). The power/iEMG area in eccentric contraction significantly decreased at higher velocities in patients ($p < 0.01$) but remained the same in controls.

DISCUSSION

The aim of this study was to investigate the relationship between different types of contractions in patients with Parkinson's disease and normal controls, with an emphasis on the stretch-shortening cycle.

Muscle strength in Parkinson's disease is decreased (18, 19, 20, 31) and the torque (19, 20) as well as the degree of muscle tonus is dependent on medication (18, 27). The results from this study confirm the impairment of muscle strength. The torque in concentric contraction diminished at higher velocities in patients as well as in controls, and the form of the curve had a similar shape in the two groups (19, 20). The eccentric torque in patients was lower than in controls, but remained at the same level with increasing angular velocity. This has earlier been shown in another study (20).

As expected, the power in eccentric contraction was larger than the power in concentric and stretch-shortening contraction in both groups. The power of stretch-shortening contractions significantly exceeded the power in isolated concentric contraction, except at slow velocity where it was the same. It is known that concentric contraction torque is higher when preceded by an eccentric contraction (2, 5, 22). This was confirmed in this study in patients as well as in controls. The recoil of elastic energy in muscles was seen only at high speed. This is compatible with the theory of visco-elasticity (7, 11, 14).

In the described test situation it seems that Parkinson patients transform torque in the combined contraction in the same way as normal individuals do.

The highest angular velocity in the test situation is similar to the angular velocity in the ankle joint during ordinary walking (24).

Dietz et al. (8) argued that to some degree hypertonia could be due to changes inside the muscles, but did not exclude changes in innervation as a possibility. The latter view or a dyscoordination in innervation can be supported by the increase in EMG described by Dietz et al. (8) and Fernandez & Blin (10) and in this study. Changes of the morphology in muscles have been reported (1), which could perhaps indirectly induce mechanical changes (26). Previous studies of objective measurements of muscle dynamics have reported an increase in muscle tone in Parkinson patients (6, 16, 26). The increased muscle tone is not believed to be caused by coactivation in antagonistic muscle (16), and in this study no coactivation of antagonistic muscles was recorded. The increase in muscle tone, probably caused by neuronal dysfunction (13) or intrinsic changes in the muscle (8, 10, 13), may be used as an extra resource in torque generation in the combined muscle contraction.

Normalised EMG recordings in normal controls have shown that large EMG levels from tibialis anterior and triceps surae are produced in gait (9), and since an increase in EMG was found in patients compared with the controls it would be appropriate to assume that patients must activate contracting muscles with excessive effort to achieve a functional movement. The fact that patients are weaker than controls (20, 23) might increase their dependence on the recoil of elastic energy in functional movements. Surface EMG recordings may show variations in interindividual reproducibility (15) dependent on the physical constitution of the person tested. Factors such as subcutaneous fat deposits, weight and the size of the muscles investigated are important. No difference in the physical constitution of patients and controls was found, which could explain the recorded differences. Electrode positions are also important. Interdistance and electrode placement were thoroughly standardised in both the tested groups to minimise the differences between individuals.

EMG recordings from eccentric and concentric contraction showed that the areas of EMG in patients exceeded the EMG areas in controls, especially in fast contraction. This was also reported by Dietz et al. (8). The power in relation to EMG activity was reduced in patients in comparison with controls, resulting in lowered efficiency in contraction. Comparison of different types of contractions within the groups indicated that in patients a lower EMG level was found during the stretch-shortening contraction. This might be explained by an inability in these patients to perform combined movements (21), and not by an increment in effectiveness in contraction, a point supported by the significant decrease in power per EMG in patients.

CONCLUSIONS

Strength production was generated in a similar manner in both groups, but with a lower contraction efficiency in the Parkinson patients. The relationships among contraction types seen in Parkinson patients were equal to those of controls, and in functional movements the Parkinson patient might benefit from the supposed increase in muscle stiffness in the combined muscle contraction.

On the other hand, the increased muscle tone registered in passive movement may not be present in the dynamic contraction, since no increase in stretch-shortening and eccentric contraction power was found.

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