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TORQUE VARIATIONS DURING REPEATED PASSIVE ISOKINETIC KNEE MOVEMENTS IN PERSONS WITH MULTIPLE SCLEROSIS

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The purposes of this study were to investigate the effect of movement repetitions on resistive torque during passive isokinetic dynamometry of the knee and to determine the role of electromyographic activity in the stretched muscles on the torque measurements. Ten persons with multiple sclerosis and hypertonia of the knee muscles were compared with 10 healthy age- and gender-matched control subjects. During series of 10 flexion and extension movements of the knee at 60, 180 and 300°/s, torque and electromyographic activity in the stretched muscles were registered. The persons with hypertonia presented a significantly larger torque reduction ($p < 0.05$) than the control subjects in all test conditions except for repeated knee flexion at 300°/s. Electromyographic activity in the stretched muscles was not identified as the only explanatory mechanism for the reduction in hypertonia during the movement repetitions, suggesting that other factors were also involved.

Key words: muscle hypertonia, multiple sclerosis, torque, dynamometry.

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INTRODUCTION

Multiple sclerosis (MS), a chronic disease characterized by inflammation and demyelination of the central nervous system, is the major cause of neurological disability among young adults in North America and Europe (1). Although treatment by means of interferon-β preparations yields promising results (2–4), symptomatic treatment remains the mainstay of treatment for the majority of persons with MS (5). One of the most frequently occurring symptoms affecting these people is spastic hypertonia (6). Spastic hypertonia has been defined as "a motor disorder characterized by a velocity dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks resulting from hyperexcitability of the stretch reflex as one component of the upper motor neuron syndrome" (7). This definition implies that spastic hypertonia is the manifestation of hyperexcitability of the stretch reflex. However, the pathophysiology of spastic hypertonia has been subject to debate. Apart from increased reflexive muscle activity, hypertonia has also been attributed to mechanical changes in peripheral structures, such as the muscles and connective tissues (8). In studies on hypertonia, registration of muscle activity is important to identify the relative role of reflexive versus non-reflexive mechanisms (9).

Spastic hypertonia may result in disordered movements characterized by slow, stereotyped and non-selective patterns and may induce contractures. However, spastic hypertonia in the lower limb extensors may also compensate for paresis and as such be a substantial help in walking and transfers (10). This fragile balance between increased muscle tone and paresis emphasizes the need for sensitive measurement methods to evaluate the progress of impairment, decide on appropriate treatment and assess its effectiveness.

The most widely applied measurement for tone is the Ashworth scale (11) or its modified version (12). However, biomechanical methods based on dynamometry have received increasing interest during the past few decades. They provide quantitative, sensitive and objective measurements of resistance against joint movements (9, 13).

Measurement of spastic hypertonia is still a challenge for clinicians and researchers. Assessment of muscle tone is complex because it is influenced by many factors. Studies have indicated that hypertonia presents distinct manifestations in active or passive movements and in different movement speeds, joints, test positions or pathologies (14–16). Furthermore, spastic hypertonia may vary throughout the range of movement, resulting in typical patterns such as catch or the clasp-knife phenomenon (17). Another factor that may induce variations in the measurement of spastic hypertonia is the reduction of resistance to passive movement during repeated movements. This feature is widely used as a basis for physiotherapy interventions such as stretching and joint mobilizations (18). To the authors' knowledge, the effect of movement repetitions on torque measurements during passive isokinetic dynamometry has been documented in only one study on subjects with spinal cord injury (19).

The purposes of the present study were: (i) to investigate the effect of movement repetitions on resistive torque during passive isokinetic dynamometry in persons with MS and in healthy control subjects; and (ii) to investigate the role of activity in stretched muscles on torque measurements during repeated movements of the knee.

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Fig. 1. Experimental set-up.

MATERIALS AND METHODS

Subjects

Ten persons with MS and 10 healthy age- and gender-matched control subjects participated in the study. The persons with MS were eligible for participation if they presented hypertonia during knee flexion and/or extension, with a minimal score of 2 on the Ashworth scale (11). Exclusion criteria consisted of (i) an unstable clinical condition or major comorbidity, (ii) pain during clinical assessment of hypertonia, (iii) orthopaedic problems in the lower limb, and (iv) range of movement in the knee smaller than 90°. The persons with MS, aged 46 ± 16 years, had a disease duration of 11.3 ± 8 years and a score of 7 (range 6–8) on the Expanded Disability Status Scale (20). The mean Barthel index (21), representing overall functional activity, was 54 (range 5–100/100). Measurements of torque were performed on the most affected side, in four persons on the right and in six persons on the left knee. The healthy subjects selected as a control group had a mean age of 46.7 ± 12 years. Both groups were composed of six men and four women. All subjects gave their written consent prior to inclusion in the study, which was approved by the local ethical committee.

Experimental protocol and measurement

A custom-made isokinetic apparatus incorporating a computer-controlled electric servomotor (Dynaserv, DR 1100/E) and a strain gauge bridge torquemeter (Lebow 2101) was used to impose repeated movements on the knee and measure torque responses. Reliability of measurements with this experimental set-up was investigated in a previous study on healthy subjects (22). The reproducibility of torques registered during consecutive repeated knee movements proved to be high, with ICC (1.1) values (23) ranging between 0.78 and 0.92.

Subjects were installed on a bench in the sitting position with the back supported. The thigh was attached to the bench with a Velcro strap and the ankle fixed in a 90° position with an orthosis (Fig. 1). The knee joint was visually aligned with the rotation axis of the motor and the lower leg attached just above the malleoli to the distal end of a rotating lever which was connected to the torquemeter.

In this position, flexion and extension movements were imposed on the knee at speeds of 60, 180 and 300°/s in series of 10 consecutive movements per velocity. High acceleration and deceleration rates (3000°/s^2) were chosen to maximize the range of isokinetic movement. During these isokinetic movements, torque generated by the resistance to the movements, velocity, as well as electromyography (EMG) of the stretched muscles, m. quadriceps femoris during knee flexion and hamstrings and m. gastrocnemius medialis during knee extension, were recorded at 1000 samples per second. EMG was registered with bipolar silver–silver chloride surface electrodes (Nikomed N4535), preamplified with active electrodes (ME3000, $A = 54$ dB, CMRR 100 dB) and amplified with a band-pass filter (5–450 Hz). Subjects were instructed to relax the leg throughout the test procedure.

Data analysis

Data were processed with a Microstar data-acquisition card (DAP1200e/6) and an on-board coprocessor. EMG data were converted to muscle activity with a differentiation technique (24). To avoid interference with inertial forces during acceleration and deceleration, the analysis of biomechanical test results was confined to the isokinetic phase of movements, which was divided into three equal parts referred to as the initial, mid and end phases of the movements. Average values of torque and EMG activity were calculated for each phase. Change in torque during the test repetitions was calculated by subtracting torques measured during subsequent movements. By this method, measurements were corrected for gravitational influences (25). Variations in torque over the test repetitions were statistically compared between the persons with MS and the control group with a linear mixed model (26). A mixed model provides a suitable approach to complex covariation structures of data, which occur in cases of many test repetitions. In a second phase, the EMG activity of the stretched muscle groups, the quadriceps muscle during knee flexion, and the hamstrings and triceps surae muscle during knee extension, was included as a covariate in the linear mixed model. This determined whether differences in torque variations between persons with MS and control subjects could be explained by the EMG activity in the stretched muscle groups. All analyses were performed with SAS, version 6.12.

RESULTS

Effect of movement repetitions on resistive torque during passive isokinetic dynamometry in persons with multiple sclerosis and healthy subjects

Figure 2 illustrates the torque variations measured in the two subject groups during 10 consecutive knee extension movements at 180°/s. The torque measured during the 10th test movement is taken as a reference to correct values for influences of gravity. Positive values represent resistive torque. In the control subjects, torque variations were minimal during the three phases of movements. The torque curves of the persons with MS presented fluctuations, especially the values measured during the end phase of movements. The largest reduction in resistive torque was found between the first and second movements.

Figure 3 gives an overview of the differences between torques measured during first and 10th flexion and extension movements at 60, 180 and 300°/s in persons with MS. The torque changes tended to be larger during movements at higher speeds and to increase towards the end of movements. In addition, torque

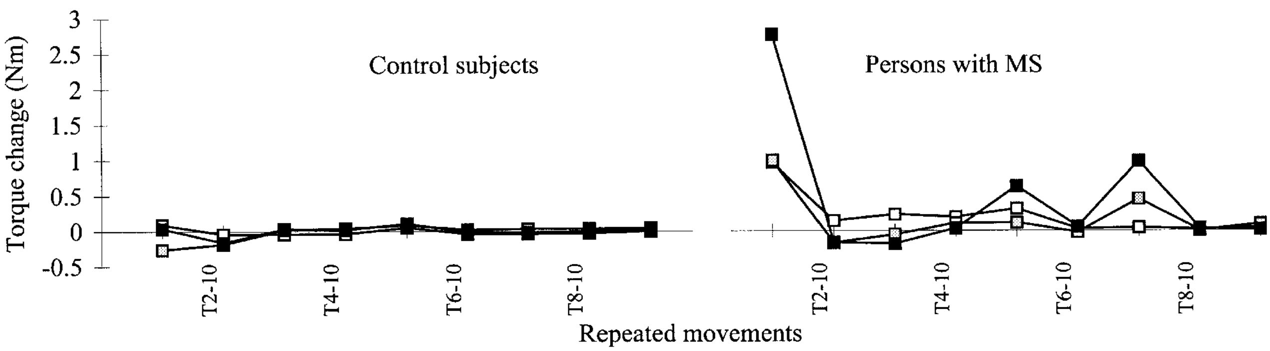

Fig. 2. Torque variation during repeated knee extension at 180°/s in 10 healthy subjects and 10 persons with multiple sclerosis. T1–10 refers to the difference in torque measured between the first and 10th test movement. Movements are divided into three equal parts referred to as initial, mid and end phases. For each phase (initial: □, mid: ▩ and end: ■), average torque values are calculated.

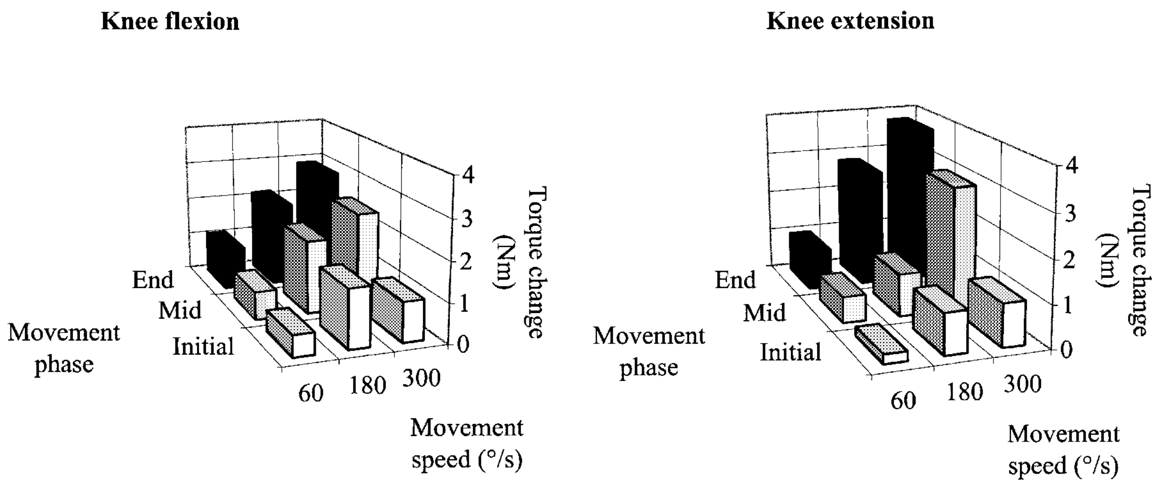

Fig. 3. Torque change between first and 10th knee flexion and extension movements at 60, 180 and 300°/s in 10 persons with multiple sclerosis.

changes tended to be more pronounced during repeated knee extension than during repeated knee flexion.

Statistical analysis of torque variations measured during the isokinetic movement sequences by means of a linear mixed model showed that during repeated knee extension, the response between persons with hypertonia and control subjects differed significantly in all test conditions ($p < 0.05$) except for the initial phase of the tests at 60 and 300°/s (Table I). During repeated knee flexion, torque variations differed significantly in the end phases at the three speeds tested, in the mid phase during the test at 180°/s and in the initial phase during the test at 300°/s ($p < 0.05$).

Role of electromyographic activity in the stretched muscle groups on torque measurements during repeated isokinetic movements of the knee

To determine whether differences in torque responses to movement repetitions in the two subject groups could be attributed to muscle activity, the EMG activity of the stretched muscle groups was included as a covariate in the linear mixed model. EMG activity can be considered as the explanatory factor for differences in torque responses to repeated movements between the two subject groups if significant *p*-values in the model without EMG become non-significant after EMG is included in the model. As shown in Table I, the interaction between repetitions and groups remained significant ($p < 0.05$) after correction for EMG, except for five test points (marked with an "a" in Table I). This finding suggests that in most cases, the EMG activity in the stretched muscle groups was not the only explanatory factor for the differences in torque responses during repeated tests.

DISCUSSION

Effect of movement repetitions on resistive torque during passive isokinetic dynamometry in persons with multiple sclerosis and healthy subjects

The results of this study show that measurement of resistance to passive knee movement in persons with MS is influenced by

Table I. *Effect of 10 movement repetitions on resistive torque during passive isokinetic knee movements in persons with multiple sclerosis* (n = *10) and healthy subjects* (n = *10): results of a linear mixed model*

Test movement		Interaction repetition group			
		Knee extension		Knee flexion	
Velocity (°/s)	Phase	*p*-Value without EMG	*p*-Value with EMG	*p*-Value without EMG	*p*-Value with EMG
60	Initial	0.08	0.10	0.50	0.001
60	Mid	0.006	0.0006	0.55	0.02
60	End	0.0001	0.0003	0.0001	0.0009
180	Initial	0.004	0.005	0.76	0.82
180	Mid	0.03	0.06[a]	0.02	0.11[a]
180	End	0.0001	0.0001	0.03	0.07[a]
300	Initial	0.49	0.0001	0.04	0.05[a]
300	Mid	0.0001	0.0001	0.08	0.002
300	End	0.0005	0.51[a]	0.03	0.0001

[a] EMG was the explanatory factor for differences in torque variations between the two groups of subjects.

repetitions of tests. Reduction of resistance to passive movement as a consequence of repeated movements is a well-recognized phenomenon. The impact of test repetitions on the response to joint movements complicates the assessment of hypertonia. To obtain more stable measurements, average torque values from several movement repetitions have been calculated (13, 18) or results from the first few tests have been omitted (27). However, the present study indicates that in persons with MS the reduction in resistive torque occurred systematically during the first few test movements. If initial measurements had been eliminated or averaged with responses during following tests, the degree of hypertonia in these subjects would have been underestimated.

To assess the degree of hypertonia, therefore, initial test movements should not be omitted or, at least, when hypertonia is measured to evaluate treatment effect or the course of impairment, the number of test repetitions should be standardized.

The torque changes as a result of repeated knee movements were more pronounced in the flexors than in the extensors. This finding may possibly be explained by some of the clinical characteristics of the persons with MS included in this study. The subjects had an average disease duration of 11 years and six persons out of 10 were wheelchair bound. In this advanced stage of MS, spinal mechanisms such as spasms may cause hypertonia to be mainly manifested in the flexors of the limbs (10). Moreover, a prolonged sitting position in a wheelchair throughout the day may induce further structural changes in the tissues. The different condition of these tissues at the flexor and extensor side of the knee may have contributed to a distinct reaction to movement repetitions.

Role of electromyographic activity in the stretched muscle groups on torque measurements during repeated isokinetic movements of the knee

The results of the linear mixed model indicated that muscle activity was the explanatory factor for differences between responses in persons with hypertonia and control subjects in some test points, more specifically in tests at 180 and 300°/s. This is not surprising since spastic hypertonia is defined as a velocity-dependent phenomenon (7). Torque variations in test conditions where EMG activity was not the explanatory factor could be due to non-reflexive mechanisms. The most probable hypothesis is the influence of thixotropic features of muscles, manifested by a reduction in resistance to movement during initial tests as a result of tearing of bridges between actin and myosin filaments (28).

CONCLUSIONS

The present study indicates that resistance to passive movement in persons with MS is reduced by repeated movements. Although a small number of subjects was tested, significant differences were found between the responses of persons with hypertonia and control subjects. This finding requires attention in the assessment of muscle hypertonia. Omitting results from initial test movements or calculating an average torque value on the basis of a movement sequence leads to underestimation of the degree of hypertonia and possibly masks a typical feature of spastic hypertonia. The response to repeated movements involved both reflexive and non-reflexive mechanisms, a finding which is an argument for the further use of EMG to obtain a more comprehensive picture of torque responses to passive movements in persons with spastic hypertonia.

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