한국전문물리치료학회지 제 14권 제 4호
PTK Vol. 14 No. 4 2007.

Correlations Among Objective Measurements of Spasticity in Patients With Brain Lesions

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Abstract

The purpose of this study was to investigate correlations among objective measurements of spasticity in patients with brain lesions. Thirty-two stroke and traumatic brain injury subjects participated in the study. Spasticity was quantified using the knee first flexion angle, relaxation index obtained from a pendulum drop test, and the amplitude of a knee tendon reflex test. Pearson's product correlation coefficient was used to examine relationships among these measurements of spasticity. There was a significant positive correlation between the relaxation index and knee first flexion angle in patients with brain lesions ($r=.895$, $p<.01$). There was also significant negative correlation between the amplitude of knee tendon reflex and relaxation index ($r=-.612$, $p<.01$), and between amplitude and knee first flexion angle ($r=-.537$, $p<.01$). Thus, it is possible to use the knee first flexion angle as an objective measure of spasticity, rather than relaxation index, which is more complicated to obtain. Further studies are needed to explore the effects of functional improvement and long-lasting carryover effects of spasticity using a simple objective measure such as the knee first flexion angle from a pendulum test.

Key Words: Amplitude; Relaxation index; Spasticity.

Introduction

Spasticity caused by injury to the central nervous system (CNS) impedes the progressive rehabilitation of patients with motor disturbances (Dimitrijevic and Soroker, 1994). In the United States, over 60,000 people per year suffer CNS injuries (Seib et al, 1994). Spasticity is a complex phenomenon, and as such, has prompted many definitions (Pease, 1998), of which that of Lance (1980) is most widely accepted (Daly et al, 1996). Lance (1980) defined spasticity as a motor dysfunction characterized by increases in tendon reflexes and tonic stretch reflexes along with an increase in the speed of joint motion as a result of hyperexcitability in the stretch reflex displayed in upper motor neuron syndrome. The pathophysiological mechanisms of spasticity remain in completely understood (Pease, 1998).

Spasticity can either facilitate or hinder functional recovery. The beneficial effects of spasticity are the maintenance of muscle mass, mineralization of paralyzed limb bones, reduced development of dependent edema and deep vein thrombosis, and increased stability of limbs during standing or walking (James a nd Teresa, 1998). In contrast, the disruptive effects of spasticity include difficulties in moving, walking, or balancing caused by myoclonia in the muscles related to gait, limited range of motion, joint contracture, pain, sexual dysfunction, decreased perineal hygiene, and difficulty in maintaining an indwelling catheter (James and Teresa, 1998).

Various approaches are currently used in the treatment of spasticity. The systemic approach uses pharmacological therapy, whereas the local approach involves physical therapy, neurolysis with a chemical agent, and surgical therapy involving selective poste-

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rior rhizotomy (Carr et al, 1995; Losseff and Thompson, 1995). The systemic approach has some limitations because of side effects such as hepatic toxicity, and the lack of selectivity (James and Teresa, 1998). Neurolysis with phenol or alcohol often causes pain (James and Teresa, 1998). Instability in the hip joint and in the lumbosacral region are reported complications of selective posterior rhizotomy (Greene et al, 1991).

It is important to develop objective measurements of spasticity, which are necessary to determine the therapeutic effects of spasticity (Jamshidi and Smith, 1996; Lehmann et al, 1989). Muscle stretch is a method used to evaluate spasticity, this can be quantified by physiologic testing, using the pendulum test or the tendon reflex test. the muscle stretch reflex is of two types: tonic or phasic. Previous research that quantified stretch reflexes measured either tonic or phasic properties, using the pendulum test or the tendon reflex test respectively. Methods to quantify spasticity objectively include biomechanical analysis of the torque generated during passive or active movement of joints and EMG signals and electrophysiological analysis using EMG signals such as H reflex, F wave, and the pendulum test (Fung and Barbeau, 1994; Haas and Crow, 1995; Hagbarth, 1994; Jamshidi and Smith, 1996). Of the electrophysiological methods, the tendon reflex test measures the spasticity of patients with CNS illness and is widely used to diagnose conditions such as peripheral radiculopathy (Kim, 2001). However, there are some difficulties in obtaining the amplitude, which indicates the quantified signal of spasticity. It requires expensive equipment such as EMG and considerable skill to tap the tendon correctly. Furthermore, the method is time-consuming, and the inter-test reliability is relatively weak (Kim and Weon, 2007). The pendulum test is a method to quantify spasticity by measuring vibration in the knee joint (Bajd and Bowman, 1982; Bajd and Vodovnik, 1984). The relaxation index, from the pendulum test, is widely used to estimate spasticity. However, it also requires extensive effort and costly equipment to measure the range of motion of the knee joint over time to calculate the index. In contrast, expensive equipment is not required to measure the range of motion of the knee first flexion angle, which can be estimated simply using a plastic goniometer.

There is insufficient research about the correlation of objective measures of spasticity. Thus, the aim of this study is to evaluate the correlation between the relaxation index and deep tendon reflexes using a pendulum test, which is a relatively objective and quantitative method to determine spasticity from the of knee first flexion angle.

Methods

Subjects

The subjects were thirty-two patients diagnosed with stroke or traumatic brain injury. They volunteered to participate in this study via Institutional Review Board approved informed consent procedure. The following screening criteria were used for patient selection: (1) grade I or above on the Modified Ashworth Scale (MAS) for spasticity in the quadriceps femoris muscle; (2) no abnormal findings in the musculoskeletal system of the knee joint; (3) capable of understanding and following directions by a researcher during the research; (4) brain injury, at least 6 months after trauma, or stroke, at least 6 months post onset.

Participants in this study were not required to stop taking previously prescribed anti-spasticity medication, but were asked to maintain constant dosages throughout the study period.

Research Instruments

Noland-Kuckhoff Table (N-K table)

N-K table[1] was used for free descending pendular movement of the knee joint. N-K table, which is

1) Preston, NJ, U.S.A.

composed of a seat, calf anchoring supporter, and weight anchoring supporter, has been developed to enhance various limb muscles. Only the calf anchoring supporter was used by separating it from the weight anchoring supporter for free movement of calves during the pendulum test. A .45 ㎏ of plastic calf anchoring frame was designed to be used during the pendulum test to minimize any influence from the 1.55 ㎏ of the anchoring frame attached to the calf anchoring supporter.

Electrical Goniometer

The electrical goniometer used to measure angle changes in the knee joint was Autogon II[2]. One axis of the electrical goniometer was matched with the axis of the calf anchoring supporter of N-K table and the other axis was attached parallel to the wooden anchoring frame so that angle changes were measured according to the movement in the calf anchoring supporter.

MP100WSW

The electrical goniometer was used to measure angle changes in the knee joint on the calf anchoring supporter of N-K table during the pendulum test. The angle changes according to movement in the knee joint and time change was converted to a graph through MP100WSW[3], a type of multi purpose ploygraph with a possible digital process (MP100 System Guide, 1997).

Quadriceps Tendon Reflex Test Instrument

The latency and amplitude during the quadriceps tendon reflex test was measured by the electric reflex hammer attached to Sapphire Premiere[4], an electromyogram appratus. A surface electrode was attached to rectus femoris muscle, and electromyogram signals of amplitude during the quadriceps tendon reflex were processed with MP100WSW.

Experiment Procedures

The assessment order of spasticity for the pendulum test and knee tendon reflex test were randomly decided through coin throwing to avoid any order effect.

Pendulum Test

The pendulum test was performed based using the method of Bajd and Vodovnik (1984) after tying up calves on the calf-anchoring supporter of the N-K table with the patient seated (Figure 1). Forty-five kg plastic calf-anchoring frame was designed to guide the motion in the 2-D plane, and to fit the joint axis. The electrical goniometer was used to measure angle changes in the knee joint on the calf-anchoring supporter of the N-K table during the pendulum test. Angular change during pendulum motion was recorded and analyzed using angular change during pendulum motion was recorded and analyzed using MP100WSW. The electrical signals from the electrical goniometer were converted into angles through MP100WSW. The electrical signals generated from the electrical goniometer were .7995 V at 90°and 1.315 V at 180°each. One axis of the electrical goniometer was matched with the axis of the calf anchoring supporter of the N-K table, and the other axis was attached in parallel with the wooden anchoring frame so that the angle changes were measured according to the movement of the calf anchoring supporter. Spasticity measured using the pendulum test was obtained using the relaxation index (RI) (Bajd and Bowman, 1982). Which was defined as the ratio between the amplitude of the first swing A0 and the difference between the starting and resting angle A1 (Figure 2). The RI was measured 10 times at 30 seconds interval. Results exceeding twice the standard deviation among the 10 measurements were discarded (Bajd and Vodovnik, 1984).

2) Jtech Co., UT, U.S.A.
3) Biopac System Inc., Santa Barbara, CA, U.S.A.
4) Medelec Co., Germany.

Figure 1. The posture for pendulum test.

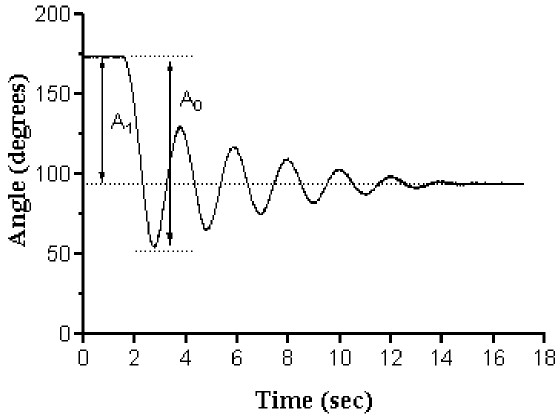

Figure 2. The Graph of pendulum test.

Tendon Reflex

The Kuruoglu and Oh (1993) method was used for the quadriceps tendon reflex test. After the patient was seated on the N-K table with the knee joint bent at 90°, a surface electrode was attached to the skin of the rectus femoris muscle right in the center on a line connecting the anterior superior iliac spine and the patellar superior border, and a reference electrode was placed on the patellar superior border. AE-131 circular surface EMG disposable electrode[5] was used to measure electromyogram signals. These electrodes were arranged into an equilateral triangular form which the center-to-center distance of three round metal discs with a 12 ㎜ diameter was 20 ㎜ while two active electrodes were arranged according to the direction of muscle fibers, and the base electrode was arranged either outer or inner part. The test was performed by tapping the quadriceps tendon with an electric reflex hammer and recording the reflexic compound muscle action potentials 10 times each with a 10 second interval before the next tapping to avoid habituation using MP100WSW. The maximal amplitude of 10 compound muscle potentials were selected as latency and amplitude values (Kuruoglu and Oh, 1993; Stam and Tan, 1987). Amplitude was defined as a the peak to peak voltage difference between two positive and negative deflexion peaks.

5) NeuroDyne Medical Co., MA, U.S.A.

Statistical Analysis

Pearson's product correlation coefficient was used to find out relation among the objective measurements of spasticity. An r of .8 and above was considered a high correlation, an r of less than .8 and greater than .3 was considered moderate, and an r of .3 and below was considered a low correlation. Throughout the study, differences and correlations with $p<.05$ were considered to be statistically significant. A statistical program SPSS version 12.0 was used for statistical process of data.

Results

Among thirty-two research subjects, 21 were males (65.6%) and 11 were females (34.4%). The age distribution was ranged from 17 to 72 years old, the average illness period was 22.7 months, and the average treatment period for physical therapy was 24.7 months. There were twenty-two patients with a stroke (68.8%) and ten patients with a traumatic brain injury (31.2%) by diagnoses. By types of paralysis, there were twelve patients with an diplegia (37.6%), ten patients with a right paralysis (31.2%) and ten patients with a left paralysis (31.2%) (Table 1). Each mean±SD of objective measurements for correlation is shown in Table 2.

Table 1. General and medical characteristics of the subjects (N=32)

Characteristics	Frequency (%)
Sex	
Male	21 (65.6)
Female	11 (34.4)
Age (yrs)	49.0±14.0[a]
Illness period (month)	22.7±12.4
Types of paralysis	
Both	12 (37.6)
Right	10 (31.2)
Left	10 (31.2)
Causes of injury	
Stroke	22 (68.8)
Trauma	10 (31.2)

[a]Mean±SD.

Table 2. Mean and standard deviation of measurements for correlation

Measurements	Mean±SD
Relaxation index	1.23±.18
Knee frist flexion angle (°)	93.44±17.89
Amplitude (㎷)	.68±.35

Correlations Among the Objective Measurements of Spasticity

There was significant correlation between relaxation index and knee first flexion angle in patients with brain lesions (r=.895, p<.01) (Figure 3). An r=.895 was considered a high positive correlation.

There was also significant correlation between amplitude and relaxation index in patients with brain lesions (r=−.612, p<.01) (Figure 4). An r=−.612 was considered a moderate negative correlation.

There was also significant correlation between amplitude and knee first flexion angle in patients with brain lesions (r=−.537, p<.01) (Figure 5). An r=−.537 was also considered a moderate negative correlation.

Discussion

Wartenberg (1951) introduced the pendulum test, in which the pendular movement of the knee joint is observed for a patient seated in a chair with the lower extremities raised horizontally and then dropped. Some measurement methods used in the pendulum test include an electrical goniometer, video recording, and an isokinetic dynamometer (Stillman and McMeeken, 1995). The electrical goniometer is attached directly to the knee joint, however, the attachment is difficult and the results may vary according to the attachment area. Video recording has the disadvantages of requiring expensive equipment, specialized facilities, and time. The isokinetic dynamometer is problematic because it may restrain the free movement of knee joint because acceleration is limited to 300° per second and the board limits the flexion movement of the joint (Kim, 2001). We used the N-K table, which has been used to perform the pendulum test in a clinical setting (Kim, 2001). The pendulum test has been used to assess spasticity objectively by measuring the relaxation index. This test reflects a tonic component of spasticity because it assesses spasticity generated during stimulation by gravity (Bajd and Vodovnik, 1984). Conceding that increase of the relaxation index means decreased spasticity.

The tendon reflex travels along the Ⅰa afferent neuron through the direct stimulation of muscle spindles. It is a test mainly of the phasic component of reflexes. A decrease in the amplitude indicates decreased spasticity. The quantification of the stretch reflex is one of the most commonly used methods in studies of spasticity.

The knee first flexion angle and relaxation index by the pendulum test were strongly positively correlated (r=.895, p<.01). Thus, it is possible to use the knee first flexion angle as an objective measure of spasticity, rather than the relaxation index, which is more difficult to obtain. Both the amplitude of the deep tendon reflex and the relaxation index by the pendulum test and the amplitude and the knee flexion angle

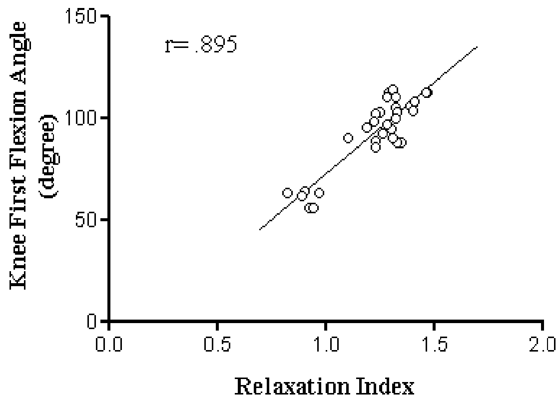

Figure 3. Correlation between relaxation index and knee first flexion angle.

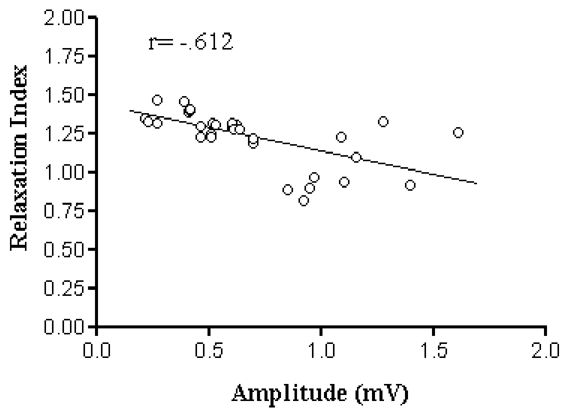

Figure 4. Correlation between amplitude and relaxation index.

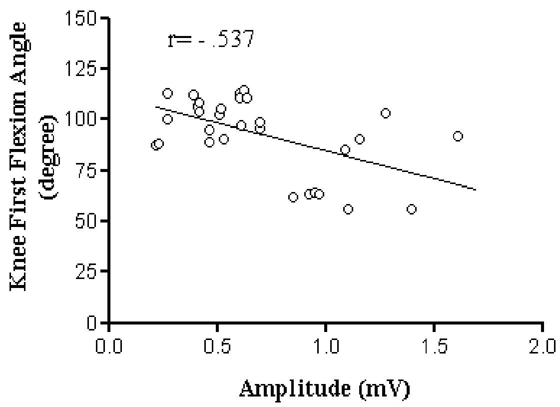

Figure 5. Correlation between amplitude and knee first flexion angle.

were negatively correlated (r=-.612, p<.01 and r=-.537, p<.01). These correlations were weaker than that between the knee first flexion angle and the relaxation index likely because the tendon reflex test reflects the phasic component of spasticity, whereas the pendulum test reflects the tonic component of spasticity.

These stretch reflexes are either phasic or tonic (James and Teresa, 1998). Phasic stretch reflexes are elicited by fast limb motion because the stretch receptors of the Ia afferent are velocity-sensitive. Tonic stretch reflexes are length dependent and likely arise from the length-sensitive discharge of group II muscle spindle afferents. A tendon reflex may be a type of phasic stretch reflex, whereas the pendulum phenomenon represents the tonic stretch reflex. The distinction between phasic and tonic stretch reflexes is important clinically because the reflexes respond differently to treatment. We used both the pendulum test representing the tonic component and the tendon reflex representing the phasic component in our correlations.

Spasticity, which is often caused by disease of the upper motor neurons, is defined as increased activity in the extension reflex according to the speed of joint movement. Spasticity can seriously impede the progress of rehabilitation therapy for patients with dyskinesia caused by CNS injury and can slow the recovery of functional capabilities such as movement and respiration (King, 1996). Thus, spasticity should be minimized to restore normal motor function. The treatment objectives are to control spasticity, facilitate normal movement, and educate patients, who need to control spasticity by themselves, and their families. According to the result of this study, the use of the simple and objective measurement of the knee first flexion angle is required in the treatment of spasticity in the future.

Conclusion

The relaxation index and the knee first flexion angle where strongly positively correlated. The knee first flexion angle is a simple, useful method with to evaluate spasticity, in contrast to the relaxation index and the amplitude of the deep tendon reflex. Further studies are needed to explore the effects of functional improvement and the long-lasting carryover effects of spasticity assessed using a simple quantitative measure such as the knee first flexion angle in a pendulum test.

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This article was received September 15, 2007, and was accepted October 25, 2007.