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The Relationship between Spasticity and Lower Extremity Strength with Functional Mobility Following Chronic Stroke

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Abstract

Background: Spasticity and muscle weakness are the primary impairments that result in activity limitation after stroke. Functional mobility is the ability to transfer independently from one place to another that depends on the extent of impairments affecting body function. The knowledge of relationship between the physical consequences of stroke and functional limitation helps therapist to implement the most effective rehabilitation approach to improve mobility.

Objective: The purpose of this study was to clinically assess the relationship between spasticity and lower extremity strength with functional mobility in hemi paretic stroke subjects.

Methods: In this cross sectional analytical study using a convenience sampling, 30 (18 men, 12 women) participants with post stroke duration of 3-24 months participated. Spasticity of knee extensor and ankle plantar flexors was evaluated with Modified Tardieu scale. Lower extremity strength was measured with Motricity Index. Functional mobility was assessed by the Rivermead mobility index, Timed Up and Go test, 6 Min Walk Test and 10-Meter Walk Test. For analysis of data the Pearson correlation coefficient was used.

Results: The results showed that there was no statistical significant relationship between the lower extremity spasticity and all functional mobility variables. The lower extremity strength and functional mobility variables were significantly correlated ($p<0.05$, $r>0.70$).

Conclusion: It seemed that lower extremity spasticity was not correlated to functional mobility after stroke. The rehabilitation for decreasing lower extremity spasticity would not be functionally efficient. There should be increased focus on rehabilitation of lower extremity strength in order to enhance functional mobility.

Keywords: Spasticity; Strength; Mobility; Stroke

Introduction

Stroke is defined as a sudden interruption of blood flow to the brain that leaded to loss of neurological function and lasted for more than 24 hours [1]. Stroke is the third leading cause of death in America and the most important cause of adult disability [2]. World Health Organization (WHO) classifies the consequences of stroke in the context of International Classification of Function (ICF) model. Based on this model, the damage often disturbs performance at three levels of “Body Function and Structure”, “Activity” and “Participation” [3]. In the first level, the impairments like hemiparesis, hyper tonicity, impaired motor control, sensory loss and decreased cognition could occur. Unilateral hemiparesis and spasticity are amongst the first neurological impairments that have the most importance for clinicians to be able to measure [4].

Spasticity is defined as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks, resulting from hyper excitability of stretch reflex [5]. Uncontrolled spasticity may lead to muscular contracture, decreased range of motion, abnormal posture and disturbed motor performance. Therefore, it has a high clinical importance for clinician to be able to evaluate the influence of spasticity on motor performance [6]. Weakness after stroke is generally manifested as either hemiparesis or hemiplegia on one side of body. Muscular weakness is characterized by the decrease in maximal velocity and capacity of force production, rapid development of fatigue [7]. Weakness is correlated with decreased ability to perform functional activities like gait speed and transfer capacity. This relationship suggests that weakness is a significant factor of diminished motor performance [8].

In general, weakness and spasticity can result in activity limitation in the level of “Activity” such as dressing, bathing and walking. Functional mobility which is the subdomain of “Activity” is defined as the ability to rolling in bed, standing from chair and transferring from one place to another [9]. The ability to walk is one of the most important factor influencing “Activity” and “Participation” in daily life. Gait deficit after stroke is well established and mainly includes both decreased walking speed and endurance. Walking speed is one of the necessary parts for mobility and transfer in the community; therefore, increased walking speed could be an indication of improved mobility [10].

Although functional limitations correlated with the extent of motor impairments; but, they are not completely dependent to them. Understanding the relation between physical consequences of stroke and functional limitations will guide the therapists to implement the most efficient rehabilitation program which results in improved mobility.

The results of studies about the relation between spasticity and walking performance in stroke patients are conflicting. Some reported that there are no relation between knee extensor and plantar flexor spasticity and gait speed [11-14]. In other researches, the relation was found between plantar flexor spasticity and gait speed [15-17]. According to these controversial results and the dearth of studies with clinical approaches to evaluation of spasticity, the importance of recognizing this relationship became prominent. Besides, most studies that evaluated the relation between muscle strength and walking performance mostly focused on special muscle group like knee extensors and also limited aspect of mobility such as gait speed. The mentioned studies mainly executed with laboratory tools. One of the new aspects of this study in comparison with previous studies is the clinical evaluation of spasticity with Modified Tardieu Scale (MTS). Modified Tardieu scale appears to be a more useful quantitative measure of spasticity in comparison with other clinical tools with high validity and inter-rater and intra-rater reliability [18]. Therefore, the general goal of this study is the assessment of the relationship between spasticity and lower extremity strength with functional mobility in hemi paretic stroke subjects.

Methods

We conducted a cross-sectional applied study of individuals with stroke undergoing rehabilitation who admitted the neuro rehabilitation clinic of Rehabilitation Science faculty at Iran University of Medical Sciences. This study is approved by the ethic committee of Iran University of Medical Sciences.

The participants were stroke patients with unilateral hemiparesis who signed the informed consent. By consecutive sampling, 30 stroke people with 6-24 month post stroke duration who were older than 40 years old entered the study. The inclusion criteria were:

- ability to walk 10 meter independently
- No history of other neurologic, orthopedic or cardiovascular disorders
- No history of injection of anti spastic drugs in recent 6 month or anti spasticity drugs 6 hours prior to study
- ability to follow multipart instructions. One who had pain in lower extremity or severe contracture and vision problems excluded from study.

One session was performed for familiarization with the place and the way evaluation would be executed. Data collection forms were used to gather information including: age, sex, height, weight, affected side, dominant side and duration post stroke. The evaluation of spasticity, lower extremity strength and functional mobility were performed consecutively in one session.

In lower extremity, knee extensor and plantar flexor were selected; because, the dominant extensor synergy in lower extremity after stroke and the important role of these muscles in walking. MTS was used for clinical assessment of spasticity. In this method, the participants lay down in a relaxed and convenient supine position. Both lower extremities were in extension position.

Each muscle was tested once in two velocities (V_1, V_3). Firstly, in V_1 (Slowest possible speed), full passive range of motion of joint (R_2) measured by the goniometer. In V_3 (as fast as possible), the quality of muscle reaction was classified based on 0-5 grade, and if the catch or clonus appeared, the R1 (angle of catch or clonus appearance) was measured in the second movement of joint. Then, the angle of R_2-R_1 was recorded [19].

Quality of muscle reaction was rated as follows:

- 0: No resistance throughout the course of the passive movement
- 1: Slight resistance through the course of passive movement; no clear “catch” at a precise angle
- 2: Clear catch at a precise angle, interrupting the passive movement, followed by release
- 3: Fatigable clonus (10s when maintaining the pressure) appearing at a precise angle
- 4: Un fatigable clonus (more than 10s when maintaining the pressure) at a precise angle
- 5: Joint is immovable

Assessment of knee extensor spasticity performed so that the knee joint was positioned in full extension and hip joint in 30° flexion. The axis of goniometer was placed on the lateral femoral epicondyle, the examiner’s one hand was above the lateral aspect of knee joint on the fixed arm and the other hand was above ankle joint on the movable arm. Then, the examiner moved the knee joint from extension to maximal flexion and measured R_2. For measuring R_1, the other one put the joint in the angle of catch or clonus and the examiner measured the angle. For evaluation of plantar flexor spasticity, the knee and ankle joints were positioned in extension. The examiner’s one hand was placed above the ankle joint, on the fixed arm which was parallel to longitudinal axis of fibula. Then, the examiner moved the ankle joint from full plantar flexion to maximal available dorsiflexion. The angles of R_2 and R_1 were recorded.

Lower extremity strength was evaluated with Motricity Index [20]. The isometric strength of hip flexor, knee extensor and ankle dorsi flexor was assessed based on weighted MRC grades.

The participants should be sitting in a chair that had back support. Hip flexion was tested with the hip joint was bent 90°. The examiner instructed the patients to bring the knee towards the chin, while she monitored the contraction of hip flexors by placing her hand on the anterior of distal thigh. Then the examiner resisted the movement. According to the quality of muscle contraction the score is recorded. Examiner also should be aware of any trick motion such as leaning the back during the movement by placing one hand on their back. Knee extension was examined while it was bent at 90° flexion with the foot unsupported, followed by the examiner asked the participants to extend the knee and touch her hand which is held at the level of the knee, meanwhile she monitored the contraction of quadriceps with her other hand which gave resistance to movement. Then the score was recorded.

Furthermore, the movement of dorsiflexion was assessed as the ankle relaxed in a plantar flexed position, then the examiner placed her hand on the forefoot, while the patient was asked to dorsi flex the foot, the examiner palpated and also resisted the contraction of tibialis anterior with the other hand on the forefoot. Finally, all three scores were summed and the Motricity Index for lower extremity was calculated (Table 1) [20].

Quality of Muscle Reaction	Motricity Score
No movement	0
Palpable contraction in muscle, but no movement	9
Visible movement, but not full range against gravity	14
Full range of movement against gravity, but not against resistance	19
Full movement against gravity, but weaker than the other side	25
Normal power	33

Table 1: Motricity Index.

Functional mobility was evaluated with the endurance of 6 Minute Walk Test (6MWT), Timed up and Go test (TUG), Rivermead Mobility Index (RMI) and the speed of 10-Meter Walk Test (10-MWT). The sequence of performing tests was not based on special order. Walking tests were completed with participants wearing their shoes and usual assistive devices. In 6MWT, the subjects were instructed to walk as far as possible along a 30 M path within 6 minute with their comfortable speed and not to stop unless they needed and the total distance was measured. Heart rate and blood pressure were monitored before, during and at the end of the test. The test repeated twice with the interval of 10 minutes and the average of these two tests recorded as an indication of walking endurance [21].

For performing 10-MWT, a measured course indoors is established with a length of 14 meters. Lines are drawn with tape at 0 meters, 2 meters, 12 meters and 14 meters. With the participant seated, the examiner instructed the participants to stand and walk to the end of line with the comfortable speed. The examiner started the stopwatch when the participant's first foot crossed the plane of 2 meter line and stopped it when the participant's first foot crossed the plane of the 12 meter line. The distance of 10 meter was divided by the time (s) taken to pass this distance. The test repeated three times with the rest of 5 minutes and the average of three trials calculated as the speed of walking [22].

TUG is a test of mobility required to stand up from a chair with armrest, walk 3 meter, turn 180° and walk back to the chair and sit down. The participants were instructed to walk in comfortable pace. The time (seconds) taken to complete this task was measured with a stopwatch. The test repeated three times and the average recorded [23].

The RMI is a dichotomous scale (0: inability to do 1: ability to do) consisting of 15 items that assess a patient's ability in performing 15 common daily movements: turning over in bed, lying to sitting, sitting balance, sitting to standing, standing unsupported, transfer, walking inside with an aid if needed, stairs, walking outside (even ground), walking inside with no aid, picking off floor, walking outside (uneven ground), bathing, up and down 4 steps, and running. Each patient's mobility performance is assessed by interviewing the patient and/or primary caregiver, except the item of "standing unsupported" which is administered by direct observation. The highest score, 15, indicates highest mobility situation [24].

Results

Thirty community dwelling individuals participated in the study. Twelve participants were female and eighteen were male. Twenty six participants had ischemic stroke and 4 had hemorrhagic stroke. Three participants used walking aid (n=1; crutch, n=2; quad cane); whereas, twenty two participants did not use any walking aid. Tables 2 and 3 demonstrated the participant's characteristics, impairment and gait measures in thirty stroke participants.

Kolmogorov-Smirnov test (K-S test) determined the normal distribution of variables (Table 2).

Statistical analysis was performed with SPSS 18, with significant level set at $p< 0.05$ (2-tailed).

Pearson product moment correlation quantified the relation between R2-R1 and lower extremity strength with functional mobility variables. As it was shown in tables 3, 4 and, the relation between spasticity and functional mobility was not statistically significant ($p< 0.05$).

Results showed that the relation between lower extremity strength and functional mobility in 30 stroke subjects was statistically significant (Table 5). Interpretation of the value of "r" is performed based on Colton [25]:

- $r < 0.5$: weak
- $0/5 < r < 0.75$: intermediate
- $r > 0.75$: high

Variable	Mean	SD	Range	K-S test
Age (month)	57.50	10.08	40-76	-
Height (Cm)	166.33	10.01	150-190	-
Weight (Kg)	67.28	11.52	45-90	-
BMI (Kg/m^2)	24.22	2.89	17.16- 29.73	-
Stroke duration (months)	13.8	3.14	6-24	-
R2-R1 Knee Ext	36.20	42.16	0-120	0.94
R2-R1 Plant Flex	10.77	10.87	0-35	0.33
TUG (s)	37.24	31.68	11.10-137	0.10
RMI	11.93	1.83	7-15	0.33
Gait Speed (m/s)	0.42	0.26	0.11-1.12	0.35
Gait Endurance (m)	139.65	86.80	28.4-316	0.59
Motricity Index	54.43	19.85	9-99	0.98

Table 2: Descriptive Statistics and Kolmogrov-Smirnov test in 30 Stroke Subjects.

Discussion

For years, therapists hold the view that spasticity is the primary cause of abnormal motor control. Recent researches have doubted this assumption. In today clinical setting, reduction of spasticity is not regarded as a clinical approach to treatment of stroke people. Nevertheless, some clinicians established their treatment based on reducing spasticity. Results of studies that examined or discussed the relation between spasticity and movement ability provide conflicting evidence. The result of this study demonstrated that there was no relation between knee extensor spasticity and gait speed which was consistent with previous studies of Nakamura et al. [14], Bohannon et al. [13] and Patterson et al. [12].

In present study, quality of muscle reaction in most participants based on Modified Tardieu Scale was mild to moderate (Quality of muscle reaction=2 or 3); therefore, it seemed that it could not be an influential factor on gait speed. Besides, in mid stance phase of normal gait, knee joint is in slight flexion that absorbs the weight. Knee extensor spasticity elicits the exaggerated stretch reflex response that inhibits knee flexion and causes knee hyperextension. In stroke subjects, the role of knee extensor muscle in gait speed is more affected by the muscle strength than spasticity; because, in mid stance the concentric contraction of knee extensor stabilizes the affected knee joint and helps the non-affected knee to have longer step and in early swing the strength of rectus femoris with other hip flexor causes the longer step in affected limb and overall increased gait speed [16].

Type of muscle	0	1	2	3	4	5
Knee extensor	N=0	N=4	N=18	N=8	N=0	N=0
Anle plantar flexor	N=0	N=0	N=10	N=20	N=0	N=0

Table 3: Frequency of participants based on quality of muscle reaction in Modified Tardieu Scale.

	RMI		10-MWT		6MWT		TUG	
Plantar flexor Spasticity	P= 0.99	r = - 0.04	P= 0.11	r = -0.56	P=0.2	r = - 0.66	P=0.38	r = 0.32

Table 4: Pearson Correlation Coefficient in Relation between plantar flexor Spasticity and Functional mobility variables.

	RMI		10-MWT		6MWT		TUG	
Lower Extremity Strength	P= 0.001	r = 0.62	P= 0.001	r = 0. 75	P= 0.001	r = 0.70	P= 0.001	r= - 0.82

Table 5: Pearson Correlation Coefficient in relation between Lower extremity strength and Functional Mobility Variables.

This study showed that there was no relation between plantar flexor spasticity and gait speed.

Also, Nadeau et al found that there was no relation between plantar flexor spasticity and gait speed [11].

This study is the first research that used Modified Tardieu Scale as a clinical measure of spasticity for assessing the relation between spasticity and gait speed. This clinical tool had privilege to be reliable and valid that could differentiate spastic hypertonia from mechanical one [26,27]. Otherwise, Lamontagne, et al. [17], Hsu, et al. [16] and Lin, et al. [15] had contradictory results. The main differences between this study and mentioned studies were the Modified Tardieu Scale and evaluation of spasticity in relaxed position. In fact, influence of spasticity during walking is different from resting position; because, during an activity voluntary contraction of muscles will alter the stretch reflex response that inevitably affects the results of assessment.

There was no statistical relation between spasticity and walking endurance. There are dearth of articles about the relation between spasticity and walking endurance. Eng et al. [28] and Pang et al. [29] found a weak relationship (r=-0/37). In these two researches Ashworth scale was used to assess spasticity. The reliability of this scale as a measure to discern spasticity from muscle contracture is not recognized.

In general, it seemed that presence of spasticity and it' grade could not be a good indicator of functional mobility after stroke. Since, it observed that spasticity in most of the cases is mild to moderate and it could not interfere with functional performance. Additionally, evaluation of spasticity in special position could not predict its contribution during walking. For better assessment, the muscle activity should be evaluated during a specific task.

Moreover, one could not neglect the role of spasticity assessment methods due to the fact that some could not measure the reflexive activity of muscle. All these factors influence the results of studies and impede the generalization of the outcomes.

The results of this study showed that all mobility variables were correlated with lower extremity strength. After stroke, hemiparesis can result in general motor impact on the muscles of affected side; therefore, muscle weakness rarely happened in isolated muscles. If some muscles were weak, probably other muscle groups would have been weak, too. In this study, the aim of assessment of three muscles in lower extremity based on Motricity Index was to be able to have a rapid overall strength of lower extremity. Most studies on the role of lower extremity strength in walking performance mainly focus on special muscles with experimental tools like isokinetic dynamometry. These tools are expensive and are not readily available in clinical setting. In normal walking, gait speed is not constant; therefore, functional assessment of muscles would not be possible. The results of this study was consistent with the results of Wade et al. [30] and Van de Port et al. [31] and Masiero et al. [32].

As yet, this study was the first one which dealt with the relation between general lower extremity strength with gait speed and endurance. Since Motricity Index evaluates the strength of three muscles which mainly produce required energy during different gait phase; therefore, it is rational that these muscles together optimized the gait speed and endurance.

Conclusion

This study demonstrated that strength deficit versus spasticity in lower extremity muscles interfered with motor performance. The implication is that reduction of spasticity may not necessarily result in improved function because other impairments like weakness may interfere; as a result, muscle weakness should be regarded as an important factor in clinical evaluation and treatment.

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