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Analysis of Spasm and Periodic Leg Movement in Spinal Cord Injury

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Abstract- Spinal Cord Injury (SCI) is an injury to the spinal cord that results in paralysis and loss of sensation. Successful recovery depends upon how well these chronic conditions are handled day to day. SCI people have very often periodic leg movement and severe spasm. Both are serious problems in the SCI population which is not always managed effectively. This is likely due to the fact that the syndrome can have various presentations, each with their own specific etiology. Hence this paper presents the overview of analysis of spasm and periodic leg movement in spinal cord injured persons using electro-myogram signals. There is a need for better understanding the syndrome of periodic leg movement and spasticity in SCI persons. So, the main purpose of this paper is to provide an integrated source of information that reflects the most useful knowledge about the main problems of SCI like periodic leg movement and severe spasm from different perspectives.

Keywords: Spinal cord injury, Periodic leg movement, Spasticity, Electromyogram

I. INTRODUCTION

Each year, 11,000 people experience a SCI. 200,000 more people are living with SCI results. When a person suffers a SCI, information traveling along the spinal nerves below the level of injury, will be either completely or partially cut off from the brain, resulting in Quadriplegia (Tetraplegia) or Paraplegia. An injury to the upper portion of the spinal cord in the neck can cause quadriplegia-paralysis of both arms and both legs. If the injury to the spinal cord occurs lower in the back it can cause paraplegia-paralysis of both legs only. The degree at which the person is paralyzed can vary. Depending on the location of the injury, paraplegics have full use of their arms and hands. Most of the researchers and clinicians use ASIA – American Spinal Injury Association scale for estimating the level of SCI injury [23]. According to ASIA scale

A – Complete: no sensory or motor function preserved in sacral segments $S_4 – S_5$

B – Incomplete: sensory, but no motor function in sacral segments

C – Incomplete: motor function preserved below level and power graded < 3

D – Incomplete: motor function preserved below level and power graded 3 or more

E – Normal: sensory and motor function normal

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As many of our reflex movements are controlled by the spinal cord but regulated by the brain, when the spinal cord is damaged, information from the brain can no longer regulate reflex activity. Reflexes may become exaggerated over time, causing spasticity. Autonomic dysreflexia is a life-threatening reflex action that primarily affects those with injuries to the neck or upper back. It happens when there is an irritation, pain, or stimulus to the nervous system below the level of injury. The irritated area tries to send a signal to the brain, but since the signal isn't able to get through, a reflex action occurs without the brain's regulation [13, 14 & 15]. Despite its prevalence, spasticity as a syndrome in the SCI population is not always managed effectively. This is likely due to the fact that the syndrome can have various presentations. Hence, this review paper summarizes the symptom and path physiology of the various presentation of spasticity in the SCI population and discusses the currently accepted management techniques.

1.1 Spinal cord injury

The spinal cord is a collection of nerves that travels from the bottom of the brain down back. There are 31 pairs of nerves that leave the spinal cord and go to arms, legs, chest and abdomen. The spinal cord is very sensitive to injury. Unlike other parts of body, the spinal cord does not have the ability to repair itself if it is damaged. A SCI when there is damage to the spinal cord either from trauma, loss of its normal blood supply, or compression from tumor or infection. Spinal cord injuries are described as either complete or incomplete. In a complete SCI there is complete loss of sensation and muscle function in the body below the level of the injury. In an incomplete SCI there is some remaining function below the level of the injury. In most cases both sides of the body are affected equally. Next section gives the brief idea about the spasm and involuntary reflex movement (mainly periodic leg movement) caused by SCI.

1.2 Spasm in SCI

SCI individuals are commonly afflicted by spasticity, but the way spasticity manifests itself varied greatly and depends on the level and completeness of the injury. Spasticity is a complex phenomenon and may consist of hyper reflexia-clonus, increased muscle tone or periodic leg movement and spontaneous muscle spasms. The severity and distribution of such spastic activity can change over time.

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The mechanisms of muscle spasticity and periodic leg movement after SCI are not well understood. Recent studies [31] indicate that the loss of particular descending axonal pathways most likely results in the decreased activity of inhibitory inter neurons, which causes the overreaction of motor neurons to excitatory stimuli that leads to periodic leg movement. Reflexes may become exaggerated over time, causing spasticity and periodic leg movement. If spasms become severe enough, they may require medical treatment. For some, spasms may be useful, since spasms can tone muscles that would otherwise waste away [2]. Some people can even learn to use the increased tone in their legs to help them turn over in bed, propel them into and out of a wheelchair, or stand [6].

According to many researchers [21] there can be many stimuli that cause autonomic dysreflexia or periodic leg movement. Anything that would have been painful, uncomfortable or physically irritating before the injury may cause autonomic dysreflexia after the injury. The most common cause seems to be overfilling of the bladder. This could be due to a blockage in the urinary drainage device, bladder infection, inadequate bladder emptying, bladder spasms, or possibly stones in the bladder. The second most common cause is a bowel that is full of stool or gas. Other causes include skin irritations, wounds, pressure sores, burns, broken bones, pregnancy, ingrown toenails, appendicitis, tight or restrictive clothing or pressure to skin from sitting on wrinkled clothing and other medical complications. Many researchers have proved that it is possible to reduce the severity of the spasm and automatic dysreflexia by using ergonomically designed wheel chair and equipments [31]. But, unfortunately many are unable to find the stimulus causing autonomic dysreflexia or periodic leg movement. Since all physicians and Spinal cord injured persons are not familiar with autonomic dysreflexia or hyper reflexia which causes periodic leg movement and its treatment. Hence this review paper discusses the EMG analysis methods for periodic leg movement and spasm in spinal cord injured persons. Section 2 describes the review of EMG analysis for periodic leg movement and spasm.

II. EMG ANALYSIS FOR SCI

After SCI, paralyzed muscles still exhibit EMG, and by definition, this EMG is involuntary. Involuntary EMG can be in the form of muscle spasms brought about by some type of stimulus or there may be just spontaneously active motor units. Involuntary EMG has been studied by many researchers [18, 19 & 20] at the single motor unit level, as muscle spasms or in long term recordings. These types of activity have only been explored in the laboratory environment over short time periods [17]. When the EMG signal is analyzed, a measure of work done by the muscle, called an activity index, can be derived. In practice, an activity index for a specific muscle is established as a benchmark. This benchmark is then compared to another activity index of the same muscle, but generated under a different set of conditions, such as after fatigue, or after the administration of a drug, etc. This comparison normalizes the activity index and provides a way of measuring the effect fatigue or the drug had on the muscle of the SCI person.

Involuntary EMG activity has been recorded in the muscles of spinal cord injury subjects for only short time periods, but it is unknown if this motor unit activity is ongoing. Longer duration EMG recordings can investigate the physiological significance of this neuromuscular activity [11]. Many researchers have analyzed the involuntary movements by using Frequency and amplitude of H-reflex [1, 10 & 30]. Earlier investigations have shown that it is possible to induce locomotor activity in patients with complete paraplegia [22]. However, from these studies, the requirements to achieve patterned leg muscle activation remained unresolved. [7 & 19] both observed motor unit activity during muscle spasms in SCI subjects. [18 & 2] saw that the firing rate of most motor units increased up to the spasm peak and then decreased after the peak. The firing rates observed were similar to those seen in ramp force voluntary contractions of able bodied subjects. According to many researchers periodic leg movements can be reduced by aerobic physical exercises [22] and some have demonstrated that spasm induced automatic hyper reflexia can be reduced by considering the ergonomic aspects [4 & 5].

Spontaneous EMG activity has been observed by different investigators after spinal cord injury. While studying the use of EMG biofeedback to improve hand muscle function, [14] showed that the muscles were spontaneously active. No apparent mechanism triggered this activity. [20 & 24] similarly have studied spontaneously active motor units in muscles in humans with spinal cord injury. The periodic movements had two activity patterns either firing at around 6 Hz or sporadically at rates around 2 Hz. The authors found that these motor unit firing patterns were present in 2 minutes and 30 minute recordings.

[30] Conducted 24 hour EMG recordings in the leg muscles of rates to determine the relationship between muscle properties and the daily muscle activity. Like the previously mentioned studies, this study found that most muscles were inactive for large portions of the day, including the more active soleus muscle that contains a large proportion of slow fibers. It also showed that there was a poor correlation between the daily duration of muscle activation and the percentage of slow fibers in a muscle. The general conclusion was that muscle fiber composition is maintained even when fiber are only activated for brief periods of time. It is still unknown if muscle activity, manifesting itself in the form of spontaneously generated motor activity manifesting itself in the form of spontaneously generated motor activity or muscle spasms, is important for the health of paralyzed muscles.

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Table 1 describes the analysis and assessment of spasm and periodic leg movements in SCI by various researchers.

First Author	Level of injury	Data base	Specimen	Parameters used for analysis	Duration of observation	Methods used	Authors opinion
MT De Mello	SCI T7, T12	12	male with complete SCI	PLM / h	12, 36 hrs before and after 44 days physical training	EEG, EMG and EOG	PLM can be effectively reduced by aerobic physical exercise
,,	SCI	13	Complete SCI	PLM / h	30+45 days	EMG	No significant difference between dopaminergic agents and physical exercise
,,	SCI T7 T12	11	incomplete	PLM/ h	12 hours night	EEG EMG	PLM after physical activity were inhibited during sleep.
Andrea Maculano Esteves	SCI T9	11	Rats	PLM / h	8 days	EOG and EMG	SCI rats can be used as models to study PLM in paraplegic patients
Blair Calancie	SCI, all cervical and thoracic	229	Acute SCI	Reflex amplitude	10 days	EMG response (peak to peak)	Tendon response amplitude and reflex spread were sensitive and specific indicators in acute SCI
,,	ASIA B	229	Acute traumatic SCI	Voluntary contraction	6 weeks	EMG	Pattern and time delay of voluntary contraction recovery can be analyzed by EMG
,,,	ASIA A D	6	Chronic cervical	Involuntary contraction or jerk frequency	4 weeks	EMG	The PLM are relatively unaffected by sensory input or patient actions and can be seen when both awake and sleeping
Arthur M.Sherwood	ASIA-D or E	97	Incomplete SCI	Ashworth scale	1 hour	Multi-channel EMG	Superiority of EMG data over Ashworth category as an objective quantification of spasticity
Marcin Czyz	ASIA-D, 3D finite element model	1	21 year old male patient	Finite element analysis	NA	Imaging	The individualized FEA model of traumatic SCI enables evaluation if the influence of mechanical strain on the neurological condition of a patient directly after and two months after the injury.
Jeffery Winslow	SCI A B C			Motor unit potential	2-3 Weeks	EMG	Automatic classification of long term involuntary movements (PLM) are beneficial for SCI analysis
Amir Hassan Kohan	Cerebral palsy	11	Age 4-6	Modified Ashworth scale	1 month	H-reflex	There is no significant correlation between degree of spasticity and electrophysiological indices (H-reflex)
Chetan P.Phadke	ASIA C D	26	Motor incomplete	H-reflex modulation in m/s	1 month	H-reflex	An improvement in position-dependent and walking speed-dependent reflex modulation after SCI may indicate functional recovery.
James Xie	SCI-A	Review	SCI incomplete	Electrical perceptual threshold and SSEP	Review	EMG and H-reflex.	Electrophysiological measures provide objective measures for SCI assessment
Sheila M	SCI A B C	29	Incomplete	H-reflex	15 days	H-reflex gain threshold and amplitude	There was no difference between subjects with and without SCI in H-reflex gain, threshold or amplitude.
Lenny Lucas	ASIA A	single	incomplete	Natural pinching		EMG	Binary control algorithm can be used as an enabling algorithm to activate exoskeleton movements
NB Reese	SCI T10	40	Adult rats	Frequency and amplitude of H-reflex	30 days	H-reflex	Passive exercise can restore frequency dependent depression of spinal reflexes in a time dependent manner
Camilla Skold	SCI A or B	353	Mean age 33 years complete SCI	Involuntary movements and resistive torque	15 days	EMG	No correlation were found between passive movement provoked resistive peak torque and actual EMG activity at peak torque
HK Lim	SCI D	67 +15	Incomplete SCI	Voluntary response index (VRI)		EMG	VRI is sensitive to the severity of SCI in a way that is similar to established clinical assessment
MM Adams	SCI A B D	Review	Chronic	Spasticity	Review	Manual analysis	There is a need for better understanding of the syndrome of spasticity

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FM Reis	SCI B D	72	Wister rats aged 90 days	PLM / h	15 days	Plasma iron level	Reduced iron metabolism after SCI may be one of the reason for PLM

Table1. EMG analysis for SCI

III. CONCLUSION

With proper recording technique, the voltage pattern displayed with EMG is representative of muscle recruitment. Inferences regarding clinical syndromes, however, are complicated by interplay of neuromuscular, biomechanical, and psychological factors that may be difficult to separate. But with the help of advanced digital signal processing technologies, it is possible to analyze and assess the neurological disturbances by extracting the useful information in EMG signal. Because the applications of EMG cover a broad scope of situations including athletic injury, repetitive strain and worker injury, injury due to motor vehicle accident, chronic pain management, neurological rehabilitation, and incontinence. Hence the EMG analysis may be useful for the analysis of periodic leg movement and spasm in spinal cord injured persons.

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