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H-reflex as an Outcome Measure in Individuals with Spinal Cord Injury - A Systematic Review

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Abstract: ***Aim:*** ***The aim of the study was to explore the available evidence and literature regarding the use of H-reflex in patients with Spinal Cord Injury. Materials and methods: A literature search was conducted in December 2019 and compilation of literature that is published from 2009 to 2019 was included in the study using common search engine i.e. Pubmed. The Inclusion criteria were 1) Prospective or retrospective cohort studies, 2) studies that included only participants with spinal cord injury 3) studies that included H-reflex in any form were investigated.4) Full text articles from peer-reviewed journals were included. Studies based in the form of Experimental, Quasi experimental and observational studies were included. Exclusion criteria were 1) Studies in any other language than English were excluded.2) Studies which had been carried out on animals were excluded. Result: Thirteen articles were included and analysed in detail in this review on the basis of the selection criteria. It showed that the H-reflex can be a useful tool in evaluating the prognosis, as it assess the excitability below the level of injury. Conclusion: H-reflex is useful in diagnostic and prognostic clinical value that could be used to monitor recovery of motor function after SCI.***

Keywords: H-reflex and Spinal Cord injury, Hoffman reflex, Electrophysiological tests and SCI, Soleus H-reflex

1. Introduction

Spinal Cord Injury (SCI) is truthfully a devastating injury with profound consequences to the individual. It is recognized musculoskeletal condition that is major and is present with severe burden.[1]

Discontinuity in the spinal cord is outcome of spinal cord injury that causes impairments that are functional as lower limb weakness with involvement of sensory system [2], dysfunction of bladder, bowel, respiratory and sexual which is based on the site and level of injury according to which symptoms may be different. There is dependence of recovery of function on the type of injury weather it is incomplete or complete on ASIA scale for impairment. There is loss of sensory as well as motor functions in case of complete type of injury whereas sensory and motor function are preserved in case of incomplete injury below the level of injury so it is predicted that recovery is more in cases with incomplete type of injury when compared with complete type of injury.[3]

In a previous review, it has been stated that various electrophysiological tests are used in SCI viz. Electromyography (44%), Motor Evoked Potential (33%), Somatosensory Evoked Potential (33%), H-reflex (20%), and Nerve Conduction Studies (9%).[4]

H-reflex is an electrically stimulated reflex that is revealed in EMGs and it is considered as a significant measurement method for estimating modulation of monosynaptic reflex activity in the spinal cord. It is elicited by submaximal of the tibial nerve and recorded from the calf muscle in lower limb.[5] The pathway of the H-reflex is composed of group Ia sensory fibres which form a synapse with α-motoneurons and their axons [6] There are different types and patterns of H-reflex abnormalities, which depends upon the severity, level, and duration of the lesion which has been reported in individuals with SCI .[5]. Various neurophysiological reflex studies have been used to assess spinal sensorimotor excitability during different movement tasks. [7] Extensive research haven proven the importance of H-reflex in various conditions like Radiculopathy, GBS and other neurological disorders. The aim of this review is to explore the available evidence and literature regarding the use of H-reflex in patients with Spinal Cord Injury.

2. Materials and Methods

2.1 Search Strategy

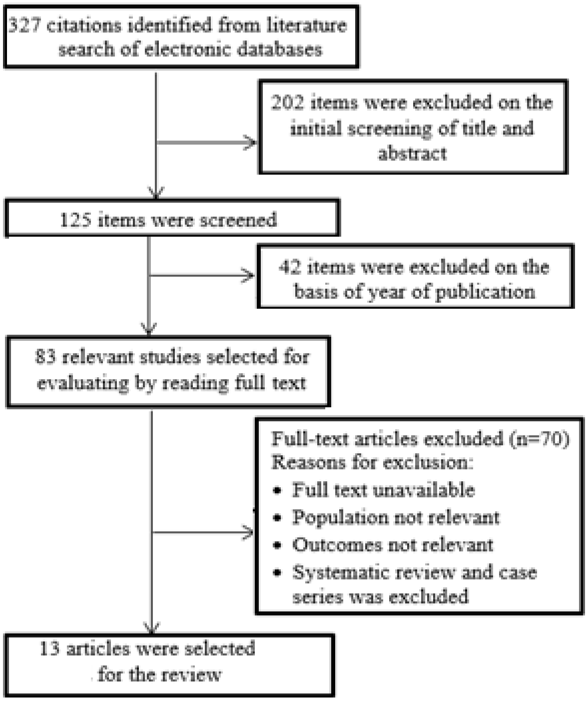
A literature search was conducted in December 2019 and compilation of literature that is published from 2009 to 2019 was included in the study using common search engine .i.e. Pubmed. The keywords used for literature search were H-reflex and Spinal Cord injury, Hoffman reflex, Electrophysiological tests and SCI and Soleus H-reflex.

2.2 Study selection and data extraction

The Inclusion criteria were:
1) Prospective or retrospective cohort studies
2) Studies that included only participants with spinal cord injury
3) Studies that included H-reflex in any form were investigated.
4) Full text articles from peer-reviewed journals were included. Studies based in the form of Experimental, Quasi experimental and observational studies were included.

Exclusion criteria were:
1) Studies in any other language than English were excluded.
2) Studies which had been carried out on animals were excluded.

Flowchart of selection criteria



3. Result

Name of the journal and year	Number of subjects	Intervention given	Outcome measure	Author and conclusion
Clinical Neuro-physiology 2013	N=9 chronic SCI	Prolonged Wide-pulse NMES was given in two patterns i.e. constant-frequency and burst frequency.	Soleus H-reflex and M wave was recorded during both the patterns.	J.M. Clair-Auger found that large H-reflex was recorded in both the patterns of NMES but burst of 100 Hz stimulation restored H-reflex to their initial amplitudes, effectively reversing the effects of post activation depression.[8]
American Physiological Society 2014	N=16 chronic SCI	BWS-assisted locomotor training with robotic exoskeleton system 45 training session, 5 days/week, 1hr/day	Soleus H-reflexes were evoked during seated and stepping at 1.0, 0.33, 0.20, 0.14, 0.11 Hz were normalized.	Maria Knikou concluded that locomotor training changed the amplitude of locomotor EMG excitability, promoted intralimb and interlimb coordination also improves premotoneuronal control after SCI in humans at rest and during walking. Synergistic group I afferents may contribute to the soleus H-reflex depression during the swing phase.[9]
The Neuroscientist 2014		20 control H-reflexes are elicited as in the baseline sessions and then 3 blocks of 75 conditioned H-reflexes (i.e., 225 total) were elicited	Soleus H-reflex is elicited while the subject maintains a natural standing posture	Aiko Thompson concluded that the Operant conditioning protocols, which can target plasticity to specific reflex pathways, might enhance functional recovery. SCI indicate that appropriate operant conditioning of the soleus H-reflex can improve walking.[10]
Neurorehabilitation 2016	N=13 normal subjects 10 iSCI	**Intervention 1:** cycling for 10 minutes on static ergometer **Intervention 2:** cycling in combination to Electrical stimulation applied to the right foot.	Reflex Modulation was assessed immediately before and after the session by H reflex H reflex modulation assessment at 25, 50, 75 and 100 interstimulus intervals.	Stefano Piazza concluded that cycling with electrical stimulation promotes spinal processing of sensorimotor function in iSCI more than cycling alone. After ES-cycling a significant increase in H-reflex excitability was observed in both the groups.[11]
Medical and Biological Engineering and computing 2018	N= 6 iSCI, 5 cSCI 13 Healthy individuals	Participants were instructed to cycle for 42rpm for 10 minutes at a resistance that is comfortable. cSCI group was assisted by electrical motor	Plantar cutaneous conditioned H reflex modulation patterns was observed during cycling and walking.	Stefano Piazza found that no modulation of soleus H reflex with plantar cutaneous stimuli was observed after iSCI or cSCI when compared with healthy population. Afferent stimulation could be adopted with diagnostic and prognostic purpose.[7]

Name of the journal and year	Number of participants	Outcome measure	Author and conclusion
International Journal of Neurosciences 2009	N= 8 chronic SCI 10 normal individuals	H reflex recruitment curve was obtained in supine seated and standing on a stable treadmill (body weight support via upper body harness)	Maria Knikou found that Soleus H reflex gain, H_{max} amplitude and H_{max} were increased in SCI subjects regardless of body position and loading.[12]
The Journal of Spinal Cord Medicine 2010	Observational study N=26 iSCI 16 normal subjects Mean age: iSCI=45±15yrs control=38±14 yrs	15 Soleus H reflex were evoked from dominant side Exp 1:26 iSCI and 16 normal patients were tested in semireclined and standing position Exp 2: 8 SCI and 5 normal patients midstance and midswing phase of walking.	Chetan P.Phadke found that H reflexes were significantly greater after SCI in all position compared with normal individuals[13]
Clinical Neurophysiology 2013	N=10 healthy individuals 10 SCI Mean age: Healthy individual=24.3±2.5 Chronic SCI= 40.2±13.7	Soleus H reflex were measured before and after the loading phase.	Shih-Chiao Tseng found that the segmental compressive load significantly decreases post activation depression in control group than in SCI. It also suggests that spinal cord reorganization mitigates the typical response to load in people with chronic SCI.[14]
Journal of Neurophysiology 2015	N=8 iSCI; mean age= 49 years N= 7 normal individuals; mean age = 40 years	Soleus H-reflex and M wave was elicited	Kim et al concluded H-reflex testing revealed normalized H-reflexes were greater for SCI than controls during passive and active lengthening. patterns of dynamic muscle activation are altered following SCI, and that greater central activation during lengthening contractions is partly due to enhanced efficacy of Ia- motoneuron transmission.[15]
Experimental Brain Research 2015	N=15 chronic SCI Locomotor training were received BWS assisted locomotor training with the help of robotic exoskeleton for 1 hour/5 days/week.	H-reflex recruitment curve was obtained from both the legs before and after the training with seated and standing position.	Andrew Smith concluded that soleus H-reflex excitability was increased in standing and decrease in seated position. Findings demonstrated that locomotor training impacts the amplitude of the monosynaptic motoneuron response based on the motor tasks in people with chronic SCI. [16]
Top Spinal Cord Injury Rehabilitation 2016	Exploratory study N= 14, Mean age :40±10 yrs	15 soleus H-reflex modulation in standing and walking was elicited in two group of SCI i.e. with and without walker	Chetan P. Phadke concluded that H reflex was greater in the walker group during stance but not in standing or swing phase.[2]
The Journal of Physiology 2019	Observational study Mean age: 49.8 ± 13.5 years N=13of incomplete SCI 7 in DC group and 6 in NS (control group).	75 Soleus H-reflex trials were obtained when subjects were made to walk on treadmill during down conditioning. H-M recruitment curve was obtained in each session for both the groups.	Aiko Thompson et al concluded that the H-reflex decrease was accompanied by improvements in walking speed and in the modulation of locomotor electromyograph activity in proximal and distal muscles of both the legs[17]
Experimental Brain Research 2019	Exploratory study N= 18 i.e. iSCI = 9 Control group= 9 Mean age: iSCI 46.3 ± 11.9 years Control group: 52.1 ± 11.3 years	Soleus Stretch Reflex, H reflex and H/M recruitment curve was obtained during natural standing and walking. Before or after locomotor stretch reflex measurements, the locomotor H-reflex were also measured by tibial nerve stimulation.	Aiko Thompson et al and colleague concluded that the H-reflex was larger in participants with SCI than in participants without injuries in the mid–late stance phase through the lateswing phase during walking.[18]

4. Discussion

After spinal cord injury, spinal sensorimotor function is disrupted below the injury level and spinal reflex activity is altered.[7] A period of spinal shock can be expected after a significant spinal cord injury, defined as a decrease in excitability of spinal cord segments at and below the level of injury. Supraspinal segmental inhibition has been confirmed by several electrophysiological studies during spinal shock, with results of presynaptic inhibition and block monosynaptic and polysynaptic reflex arcs. The pattern of reflex recovery appears to be cutaneous polysynaptic reflexes prior to the monosynaptic reflexes. [19]

The purpose of the review was to determine the use of the H-reflex as an outcome measure in individuals following SCI. Advantages of electrophysiological studies are:1) it facilitates understanding of the underlying pathophysiological mechanisms of SCI and how the neurological recovery is improved by therapeutic interventions.2) they are more sensitive, reliable and provides the quantitative data which is valuable for the diagnosis.

Various neurophysiological reflex studies have been used to evaluate spinal sensorimotor excitability during different movement tasks. Neurophysiological conditioning techniques using the soleus H-reflex as the test reflex marker of spinal excitability have also been used to improve our understanding of sensorimotor control in healthy subjects and individuals with SCI. [7]

The possible underlying mechanism could be a deficit in the modulation of proprioceptive Ia afferent activation of alpha motoneurons in people with independent or assistive ambulation after iSCI, diminished or absent inhibition of cutaneomuscular conditioned soleus H-reflex activity

Fung and Barbeau used a similar testing paradigm to quantify the effect of a cutaneomuscular conditioning stimulus on the soleus H-reflex during walking, showing that reflex inhibition was diminished or absent after moderate to severe SCI associated with the spasticity syndrome.[7]

Piazzo et al also reported whether a longer duration and repeated ES cycling intervention could lead to improvement in neuromuscular function after SCI, as observed using other clinical conditioning protocols using the H-reflex as the test measure. Change in cutaneomuscular-conditioned H-reflex excitability following ES cycling may have a diagnostic and prognostic clinical value that could be used to monitor recovery of motor function after SCI and could be applied to identify responders to new neurorehabilitation therapeutic approaches.[11]

Kim et al used H-reflex modulation across the muscle action to see the spinal reflex excitability in patients with SCI and found the increase spinal reflex excitability after SCI when compared to normal individuals during lengthening action. Further he added that the presynaptic inhibition of Ia afferent terminals as a mechanism for reduction in length of Hmax/ Mmax in normal individuals. As, presynaptic inhibition of Ia afferents is thought to be diminished following SCI.[15]

Maria Kniknou et al also reported that spinal inhibtion is reduced following SCI and it can be improved with locomotor training. H-reflex was elicited before and after the locomotor training so as to observe the changes of the soleus H-reflex long latency depression. In this study also H-reflex was used to evaluate the spinal excitability and find out the possible mechanism for the recovery in the individuals with SCI.[9] Several studies revealed peripheral NCS and intramuscular EMG detects and characterize concomitant traumatic damage to the peripheral nervous system if present, such as radiculopathy, nerve plexus damage or peripheral neuropathy, and help distinguish them from spinal cord damage. SSEPs, CHEPs, and MEPs are used for testing conduction in long spinal tracts conveying afferent somatosensory and efferent motor information across the lesion site in individuals with more severe injuries. However, such conductivity assessments of spinal tracts as SSEPs,CHEPs,MEPs are limited in terms of evaluating safety as evoked potential across the lesion are likely not recordable and thus, no baseline recording may be obtained from which to measure a detrimental change.[20] Furthermore, H-reflex and F-wave recordings not only prove integrity of the proximal segment of the peripheral nerve but also assess the excitability of LMN below the lesion. The future studies can be done particularly on the use of H-reflex in the therapeutic intervention so that to understand how the H-reflex modulation helps in recovering the motor functions in patients with SCI.

5. Conclusion

H-reflex is useful in diagnostic and prognostic clinical value that could be used to monitor recovery of motor funsction after SCI.

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